Volume 1 of 2

Macroinvertebrate Assemblages and Water Quality in Six National Park Units in the Great Plains

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1.0 INTRODUCTION

Surveys of the biological conditions of U.S. streams have indicated that most are influenced by chemical or physical alterations. As a consequence "natural" biological communities continue to be altered despite federal legislation mandating their protection. The National Park Service is concerned with the aquatic resources under their protection, and in particular, the long-term maintenance of the biotic integrity of these resources. A component of this is the ability to anticipate and predict possible future impacts to specific aquatic resources. Resource inventory and monitoring are essential elements in this process, since they provide the basis for verifying predicted impacts as well as assessing the pace and extent of any changes in the status of the resource.

This report provides inventories of the aquatic macroinvertebrates of and baseline information about the aquatic ecosystems of six small units of the National Park Service (NPS) Midwest Region, and outlines a program for monitoring the aquatic resources using biological criteria. The park units examined in this study were: Agate Fossil Beds National Monument, Nebraska (**AGFO**), Homestead National Monument of America, Nebraska (**HOME**), Pipestone National Monument, Minnesota (**PIPE**), Herbert Hoover National Historic Site, Iowa (**HEHO**), George Washington Carver National Monument, Missouri (**GWCA**), and Wilson's Creek National Battlefield, Missouri (**WICR**).

1.1 *Biological Indicators*

In their essay about science and management in the National Park Service, Davis et al. (1988) stated their "belief that long-term ecological information is essential for carrying out the mission of the National Park Service." They outlined the role of long-term ecological monitoring in Park organization and in assessing ecosystem health. Resource inventory specifies elements of the landscape that are managed by the National Park Service. Hellawell (1978) provided a definition of "monitoring" and two terms which are often used interchangeably, "survey" and "surveillance:"

<u>Survey:</u> an exercise in which a set of standardized observations (or replicate samples) is taken from a station (or stations) within a short period of time to furnish qualitative or quantitative descriptive data.

<u>Surveillance:</u> a continued programme of surveys systematically undertaken to provide a series of observations in time.

<u>Monitoring:</u> surveillance undertaken to ensure that previously formulated standards are being met.

Surveillance is a tool with which managers observe and document changes over time. In a monitoring program the parameters monitored must be chosen to reflect ecosystem change, so corrective action may be taken (Cairns 1990). One goal of long-term monitoring is to assess the natural variability of components of an ecosystem and distinguish this natural variability from anthropogenically caused changes (Likens 1985, Schindler 1987).

Karr et al. (1986) defined five classes of environmental factors that affect aquatic ecosystems: energy source, water quality, habitat quality, flow regime, and biotic interactions (Table 1-1). They stress that these classes are interrelated and the biological community may be altered by changes in any one of the factors. Therefore, the components and structure of the biological community reflect many environmental factors, making biological monitoring a powerful tool. Additionally, the integration of many environmental factors suggests that approaches to water resource management problems be broad-based. Solutions that consider many aspects of the watershed, and manage the ultimate cause of a problem, are likely to be more effective and more economical than solutions which only consider proximate causes (Karr et al. 1986, Ohio Environmental Protection Agency 1988).

Stream biota reflect the chemical, physical, and biological conditions in which they evolved. Biological community changes, and therefore biological evaluation, reflect environmental conditions and anthropogenic impacts.

Table 1-1. Environmental factors that affect aquatic biota (modified from Karr et al. 1986).

1. Food (Energy) Source

   - type, amount, and particle size of organic material entering a stream from the riparian zone versus primary production in the stream
   - seasonal pattern of available energy

2. Water Quality

   - temperature
   - turbidity
   - dissolved oxygen
   - nutrients (primarily nitrogen and phosphorus)
   - organic and inorganic chemicals, natural and synthetic
   - heavy metals and toxic substances
   - pH

3. Habitat Structure

   - substrate type
   - water depth and current velocity
   - spawning, nursery, and hiding places
   - diversity (pools, riffles, woody debris)
   - basin size and shape

4. Flow Regime

   - water volume
   - temporal distribution of floods and low flows

5. Biotic Interactions

   - competition
   - predation
   - disease
   - parasitism

Surveillance of aquatic and wetland habitat quality using macroinvertebrate species or communities as indicators of biotic integrity has become common practice. Macroinvertebrates are especially useful for this purpose because they are (a) common in most streams, (b) readily collected, (c) relatively easily identified, (d) not very mobile, and (e) generally have life cycles of one year or more. Benthic macroinvertebrates have been used to assess water quality in a number of ways including toxicological assays, bioaccumulation, indicator species, and community measures (including biotic indices, diversity indices, similarity indices, description of community structure and function). All of these approaches have been used with some success, and likewise, they each have limitations.

In their most basic form, laboratory toxicological assays expose organisms to concentrations of a toxicant and measure survival. This accounts for acute, or immediate, toxicity and tolerance of the organism. An assay is specific to the organisms and toxins or pollutants tested. This approach becomes more complex when chronic (delayed) effects, and additional stresses are considered.

A number of species have been used as "bioaccumulative" indicators. These indicator organisms accumulate polluting substances from their environment, and their tissues are analyzed for specific substances (Hellawell 1986).

The indicator species approach surveys the abundance of a population of a species that is sensitive or tolerant to a type of pollutant. This strategy is limited to the known stresses to which a species is sensitive. Sensitivity to a specific stress for a species may vary regionally or seasonally. Natural variation of populations, and species interactions complicate interpretation of data.

Biotic indices applied to invertebrate communities are an extension of the use of indicator organisms to a community (Washington 1984). These indices assign a value related to pollution tolerance to each taxon, and through a mathematical formula calculate a score. The index may or may not account for absolute or relative abundances of organisms (Hellawell 1986). Like the indicator species concept, the effectiveness of a biotic index is considered limited to certain types of pollution and to specific geographical areas (Washington 1984). Some popular biotic indices include the Trent index (Woodiwiss 1964), Chandler Biotic Score (1970), and Hilsenhoff's biotic index (1982, 1987, 1988).

Another measure of community structure is the diversity index, which consists of species richness and abundance among the species (evenness). A specific index may consider one or both of these components. These indices must be interpreted with caution since they do not consider qualitative species composition, and because of moderate disturbance diversity may increase which is naturally low in many types of communities. Commonly used diversity indices

include Shannon's H' (Shannon and Weaver 1949), Brillouin's H (1951), and Simpson's D (1949).

Similarity or comparison indices are mathematical measures of the similarity of two communities. An impacted community is usually compared to a reference site upstream or in the same region. Species composition, abundance, or both, may be measured. These indices, along with ordination techniques, have been extensively used in plant ecology (Washington 1984, Hellawell 1986). Popular similarity indices include Pinkham and Pearson's index (1976) and Jaccard's index (1912).

Components of community structure and function may be expected to change when environmental quality is impacted. Parameters, such as species richness, density, biomass, production, and functional groups are commonly measured. Any or all of these components may change with a specific stress.

1.2 *Scope of Study*

The following report is the result of a two year project originally designed to be both scientific and advisory in nature. A comprehensive analysis of the ecological status of each park unit is provided along with recommendations for long-term management and monitoring. Specific objectives include:

1. Description of the aquatic resources of each park unit and the surrounding drainage basin including
    a. selected water chemistry parameters
    b. geomorphic setting
    c. stream habitat features

d. inventory of aquatic macroinvertebrates.

2. Assessment of the current status of the aquatic resources of each park unit in terms of the composition of the macroinvertebrate assemblages.
3. Identification of areas of concern, and recommendation of management and long-term monitoring strategies.
4. Providing assistance in determining the role and effort of Park Service personnel in providing long-term monitoring information.

1.3 *National Park Service Midwest Region*

The detailed data collected at **AGFO** were intended to serve as a general background from which to derive a more simple monitoring program at other parks with similar ecological conditions and management needs. Within the National Park Service Midwest Region, **AGFO**, **HOME**, **PIPE**, **HEHO**, **GWCA**, and **WICR**, all have resource management responsibility with a first or second order stream that has a significant portions of the upstream watershed outside the boundary of the park.

These six parks are located in the plains region of North America. Streams within the plains region have similar features such as low gradient, presence of predominant silt or sand substrate, relatively high buffering capacity of the water, and a general similarity in the type and dynamics of the biological communities. Matthews (1988) provided a review of ecological characteristics of prairie stream systems.

In order to facilitate understanding patterns and management of regional ecosystems, Omernick (1987) delineated ecoregions in the conterminous U.S. These ecoregions were based primarily on patterns of land form, general type of potential vegetation, soils and land use. The National Park Service units fall into one of the following ecoregion delineated by Omernick: Western High Plains (**AGFO**), Central Great Plains (**HOME**), Northern Glaciated Plains (**PIPE**), Western Corn Belt Plains (**HEHO**), Central Irregular Plains (**GWCA**), Ozark Highlands (**WICR**). Differences in land use around the Parks predicate to a large extent the generic environmental risk to aquatic resources that is expected within the more specific ecoregion (Gallant et al. 1989). Other specific environmental risks should be elaborated on an individual stream basis.

1.4 *Acknowledgements*

The authors would like to thank the following persons from each park unit: the superintendent of **AGFO**, John B. Rapier III, and the staff of **AGFO** and Scotts Bluff National Monument for their cooperation, hospitality, and information throughout the study. Dr. Gustavo Diaz, National Park Service, Water Resources Division, Fort Collins, Colorado, assisted with the stream flow analysis. Dave Beeson identified and evaluated the qualitative periphyton samples. We also thank the Meade family for their kind hospitality and for access to their ranch throughout this study; the Superintendent, Randall K. Baynes, and staff of **HOME** for their cooperation and hospitality. Tom Ulrich, the Natural Resource Specialist, conducted macroinvertebrate and water chemistry

sampling, and made stream observations throughout the study; the Superintendent, Vincent J. Halvorson, and staff of **PIPE** for their cooperation and hospitality. Denise Boudreau, the Natural Resource Specialist, conducted macroinvertebrate and water chemistry sampling, and made stream observations throughout the study; the Superintendent, Steven A. Kesselman, and staff of **HEHO** for their cooperation and hospitality. Jerry Chilton and John McGlothen were responsible for conducting macroinvertebrate and water chemistry sampling, and making stream observations; the Superintendent, John Neal, and staff of **GWCA** for their cooperation and hospitality. Shirley Baxter, the Natural Resource Specialist, conducted macroinvertebrate and water chemistry sampling, and made stream observations. Shirley was very helpful in all phases of the study; the Superintendent, Malcolm Berg, and staff of **WICR** for their cooperation and hospitality. Rob Lamar was responsible for conducting macroinvertebrate and water chemistry sampling, and making stream observations. Rob's assistance and enthusiasm were invaluable.

2.0 STUDY AREAS

2.1 *Agate Fossil Beds National Monument*

AGFO was established in 1965 to protect concentrations of animal fossils in the 20 million year old sedimentary rock. The Niobrara River winds through the 1100 ha **AGFO** west to east. The river originates near Lusk in eastern Wyoming. It flows approximately 612 km along the northern half of Nebraska and empties into the Missouri River near Niobrara, Nebraska (Knox County) at about 381 m above sea level. The entire river basin encompasses over 30,000 km^2 (11,870 mi^2) (Nebraska Soil and Water Conservation Commission 1971). Above the U.S.G.S. gaging station near the western boundary of the **AGFO** the Niobrara River drains approximately 2200 km^2 (840 mi^2). The elevation at Park headquarters is about 1420 m.

The Arikaree Group of the High Plains aquifer system underlies the region. This aquifer system is below 85% of the State, and the Arikaree group is in the northern part of the panhandle. This group contains sand with sandy silt and concretions up to 150 m thick (USGS 1988). A test well was dug at the **AGFO** on 24 July 1967 by Meder Smith, Inc. of Alliance Nebraska. The log of the test well indicated that the geology is dominated by sand and sandrock (Fig. 2-1). The sediments are moderately permeable and of tertiary age (Nebraska Soil and Water Conservation Commission 1971).

The lands bordering the Park and most land within the region are devoted to grazing, supporting various densities of livestock.

Figure 2-1. Log of test well, drilled by Meder Smith, Inc., 24 July 1967, Agate Fossil Beds National Monument, Nebraska.

MEDER SMITH, President

MEDER SMITH, Inc.

WELLS ★ PUMPS ★ ACCESSORIES

1016 West Third P. O. Box 517 Phone 762-5791

Alliance, Nebraska 69301

July 24, 1967

LOG OF AGATE FOSSIL BEDS TEST WELL

1 - -	5 - -	Top soil & sand
5 - -	10 - -	Sand
10 - -	15 - -	Loose rocks & sand
15 - -	20 - -	Sand with some loose rocks
20 - -	23 - -	Magnesia rock & sand
23 - -	28 - -	Magnesia rock & sandrock with some fine sand
28 - -	35 - -	Sandrock & hard rock & fine sand
35 - -	36 - -	Soft sandrock & sand
36 - -	42 - -	Hard rock with little layers of sand
42 - -	46 - -	Hard course & fine sand
46 - -	47 - -	Soft & fine sand
47 - -	48 - -	Hard rock & soft fine sand
48 - -	54 - -	Hard & soft rock with intermittent 6" layers of sand between rocks
54 - -	58 - -	Course sandrock & fine sand
58 - -	63 - -	Fine black water sand
63 - -	67 - -	Layers of fine black water sand & rock
67 - -	68 - -	Sandrock & hard rock
68 - -	69 - -	Fine black water sand
69 - -	71 - -	Layers of sandrock & fine black water sand
71 - -	75 - -	Fine black water sand with very little rock
75 - -	78 - -	Soft sandrock & fine black water sand
78 - -	82 - -	About 3" alternate layers of hard sandrock & fine black water sand
82 - -	83 - -	Fine black water sand
83 - -	85 - -	Hard sandrock & fine sand
85 - -	89 - -	Very hard sandrock
89 - -	90 - -	Hard rock
90 - -	93 - -	Fine black water sand
93 - -	100 - -	Fine black water sand with layers of rock 2" to 3" thick
100 - -	104 - -	Fine black water sand with thin layers of rock
104 - -	111 - -	Fine black water sand
111 - -	112 - -	Hard rock & sand
112 - -	145 - -	Fine black water sand with few thin laye rs of rock (33' which wou[ld] make ggod well without any of the other water formations.)
145 - -	153 - -	Sandrock & fine brown sand
153 - -	187 - -	Sandrock & rock with fine sand
187 - -	193 - -	Sandrock & rock
193 - -		Hit sanother rock fracture & lost water immediately
193 - -	200 - -	Soft sandrock with thin layers of rock & runs of light brown sand
200 - -	208 - -	Soft sandrock & small layers of sand
208 - -	239 - -	Soft sandrock with layers of light brown sand & some rock layers

Water level - - 36' 4"

PUMPS ◆ SPRINKLING SYSTEMS ◆ WELLS

In the surrounding area there is also dryland agriculture and some irrigated cropland (mostly alfalfa hay). Above the U.S.G.S. gaging 4station bordering the Park, approximately 2700 ha are irrigated from diversions of the Niobrara River. Above Box Butte Reservoir approximately 5200 ha are irrigated (Hydrodata 1989).

Center pivot irrigation circles also occur upstream of the **AGFO**. The underground water area of the Niobrara in the **AGFO** are part of the Northern Panhandle Tableland Region. Groundwater levels in the region have declined because of pumping for irrigation (Nebraska Soil and Water Conservation Commission 1971). The 1971 test well at the **AGFO** indicated groundwater levels at about 11 m (Fig. 2-1).

The **AGFO** is part of the Great Plains Physiographic Province, which extends east from the base of the Rocky Mountains (about 1675 m) to approximately the 100th meridian (also the 600 m contour and 50 cm rainfall line), to the boundary between the short and tall grass prairie (Hunt 1974). Along with the Osage Plains Province, it makes up the prairie region of North America (Matthews 1986). The **AGFO** lies in the "dissected plains" topographic region. The plains are rolling with the relief ranging from 1 m to 60 m (Nebraska Natural Resources Commission 1974). The **AGFO** falls on the boundary of two of Omernick's (1987) ecoregions, the Northwestern Great Plains and Western High Plains.

Within the **AGFO**, aside from a narrow river corridor, the vegetation is classified as prairie (Stubbendieck and Willson 1986). Stubbendieck and Willson (1986) reported that the Küchler

potential natural vegetation as the grama-needlegrass-wheatgrass type (blue grama, Bouteloua gracilis (H.B.K.); needlegrass, Stipa comata Trin & Rupr; western wheatgrass Agropyron smithii Rydb.) (Küchler 1964). The prairie has been reported to be in good condition (Landers 1975) and a prairie restoration and management program is ongoing.

Historically, homesteading began in the North Platte Valley around the turn of the century. Between 1904 and 1950 the Agate Fossil Beds were the focus of scientific excavations. Until creation of the Park, the land was grazed by livestock with local areas of cultivation and areas of sustained heavy grazing (Landers 1975).

AGFO lies in the arid northwestern region of Nebraska. A National Climatic Data Center weather station is located on the **AGFO** and data may be accessed through the Climatedata (1989) CD-ROM data base. From May 1948 through December 1988 the **AGFO** received an average of 369 mm of precipitation. May had the highest mean precipitation, and December the lowest. The mean monthly precipitation is presented in Table 2-1. The average yearly snowfall was 793 mm, and the mean monthly snowfall is presented in Table 2-1 (Climatedata 1989).

The mean monthly, daily maximum temperature ranged from 2°C (January) to 31°C (July) for the time period of September 1964 through December 1988. The mean monthly daily maximum temperatures are presented in Table 2-2. The yearly, mean daily maximum temperature was 17°C. Mean daily minimum temperatures were

Table 2-1. Mean monthly and mean annual precipitation and snowfall at Agate Fossil Beds National Monument, Nebraska. Precipitation records May 1948 - December 1988. Snowfall records September 1948 - December 1988 (Climatedata 1989).

Month	Precipitation (mm)	Snowfall (mm)
January	11	133
February	9	91
March	16	159
April	35	118
May	73	29
June	69	2
July	53	0
August	39	0
September	31	18
October	19	39
November	9	83
December	8	113
Mean Annual	369	793

Table 2-2. Mean monthly and annual, daily minimum and maximum temperatures (°C), Agate Fossil Beds National Monument, Nebraska. Daily maximum temperatures records September 1964 - December 1988. Daily minimum temperatures records July 1965 - December 1988 (Climatedata 1989).

Month	Minimum	Maximum
January	-14	2
February	-10	5
March	- 6	10
April	- 2	16
May	3	21
June	8	27
July	11	31
August	10	30
September	4	25
October	- 2	18
November	- 8	9
December	-14	3
Mean Annual	- 1	17

recorded from July 1965 through December 1988, ranged from -14° to 11°C, and are presented in Table 2-2. The yearly mean daily minimum temperature was -1°C (Climatedata 1989). The frost free period is approximately 125 to 140 days (Nebraska Natural Resources Commission 1974).

A shifting sand and sand/mud substrate is characteristic throughout the length of the Niobrara River in the **AGFO**. The aquatic macrophyte Potamogeton pectinatus L. was locally abundant, forming green mats covering the stream bottom. Several graminoid species overhang along the eroded and undercut banks, although willow is the dominant riparian vegetation along many reaches within the **AGFO**. Sandbar willow (Salix exigua Nutt.) is abundant and peachtree willow (Salix amygdaloides Anderss.) occurs less frequently. An introduced Siberian Iris is locally abundant in the Park. During the winter months the river often occupies floodplain reaches due to ice jams that form due to an irrigation structure outside the eastern boundary.

2.1.1 Study Sites

Three study sites were established along the Niobrara River at the **AGFO** in spring 1988 (Fig. 2-2). Site 1 (AFB1) was located east of the State Highway 29 bridge. The channel was narrow, about 1.3 m. The banks are undercut and have an abrupt drop-off. Herbaceous vegetation dominated the streamside vegetation. In June 1989 Site 1 was relocated, to a location more suitable for the placement of Hester-Dendy artificial substrate samplers, about

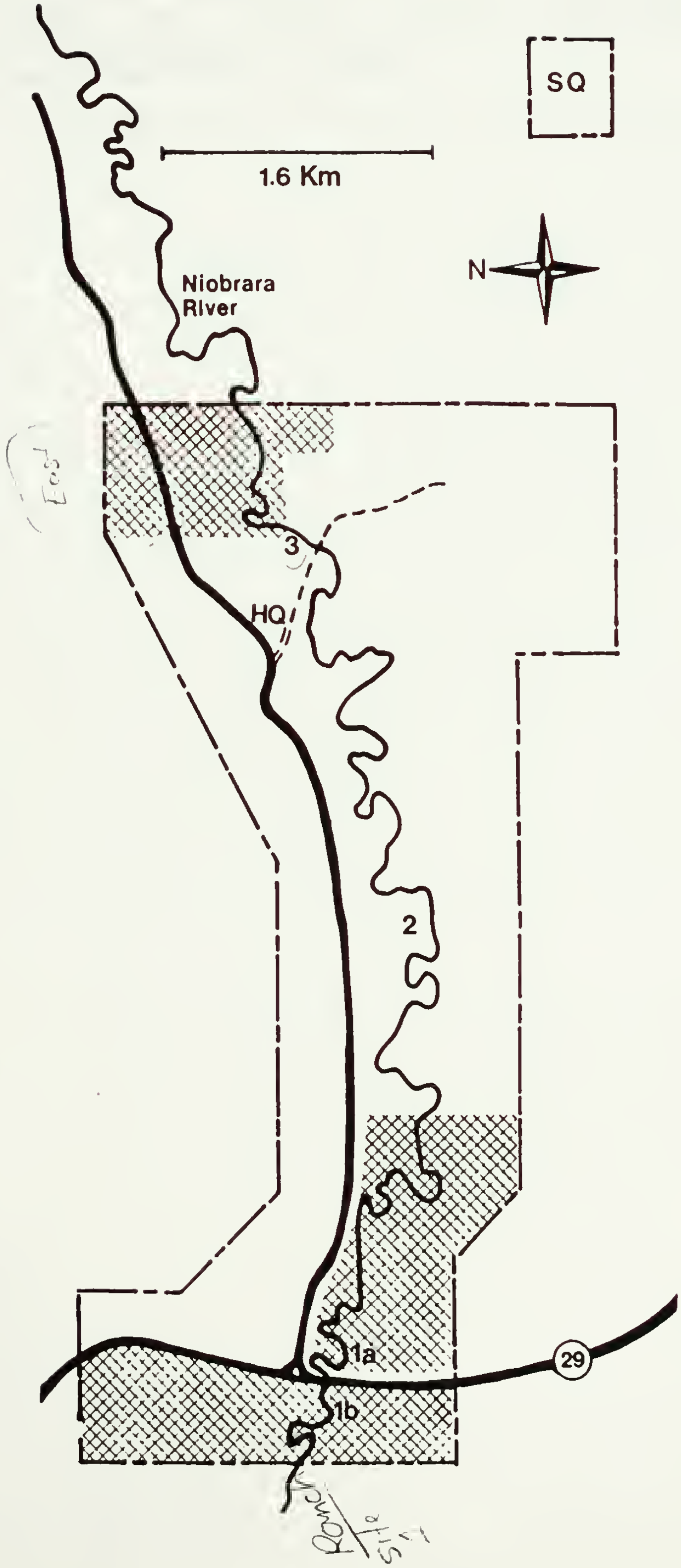

SQ
1.6 Km
N
Niobrara
River
3
HQ
2
1a
1b
29

Figure 2-2. Map of Agate Fossil Beds National Monument, Nebraska. Hatched area represents land within boundary that is privately owned; 'HQ' - Headquarters area; 'SQ' - Stenomylus Quarry, detached Monument land; '1a' - Site 1 for Hess sampling; '1b' - Site 1 for Hester-Dendy sampling; '2' - Site 2; '3' - Site 3 (Redrawn from National Park Service brochure).

110 m west of the Highway 29 bridge. Dense growth of Siberian Iris was present here, and a few cottonwood (Populus deltoides Marsh.) provided some canopy. Near the highway bridge groundwater upwelling is evident. Site 2 (AFB2) was located 25 m west of the road leading to the ranger residence. This site was not used in the 1989 - 1990 sampling year. A willow thicket was present on both banks. Site 3 (AFB3) was near the visitors center. It was 150 m east of the visitors trail about 25 m before the trail crosses the river. The stream flows north at this site. A 2.5 m tall willow thicket dominated the east bank, while graminoids covered the west bank.

2.2 *Homestead National Monument of America*

HOME was established in 1936 to commemorate the pioneers of the homestead movement. This Park is located in the loess plains of southeastern Nebraska. It is on a T-shaped quarter section, about 65 ha (160 acres), in Gage County about 7 km (4.5 mi) west of Beatrice.

Cub Creek winds through the western half of the **HOME**, joining the Big Blue River about 3 km below the Park. Twice the stream exits and reenters **HOME** property before exiting the northern boundary. The entire Cub Creek watershed encompasses 374 km^2 (144.3 mi^2). The substrate of the stream consists of fine and coarse sand, and contains a large amount of organic material. The stream banks often rise abruptly and the stream has a partial woody canopy. Flood control and sediment dams have been constructed upstream of the **HOME** as part of a project across the entire Big

Blue River Basin. Historically, flooding has been part of the hydrologic regime of the Big Blue River. Extreme variation in flow depth and velocity are common in the creek. Additionally, beavers are active throughout Cub Creek.

Approximately 40 ha (100 acres) has been restored as tall grass prairie, and about 25 ha (60 acres) of hardwood forest grow in the bottomlands bordering Cub Creek. The Küchler potential natural vegetation of the **HOME** is bluestem prairie (Andropogon-Panicum-Sorghastrum) (Küchler 1964, Stubbendieck and Willson 1986). Prairie restoration has been conducted since 1939. Land use around the **HOME** is primarily agricultural, with some pasture and woodland.

June through September are the wettest months of the year, and averages 77 cm of precipitation a year. The wettest year on record is 1951, when the area received 123 cm of precipitation and the driest year was 1974 (34 cm). An average of 70 cm of snow falls primarily December through March (Climatedata 1989).

2.2.1 Study Sites

Two sites were established on Cub Creek for water chemistry and benthic macroinvertebrate analysis. Site 1 (HMS1) is located in the southwest corner of the **HOME** about 50 m inside the **HNMA** boundary. Site 2 (HMS2) is located about 50 m northeast of State Highway 4 before the stream exits **HOME**. Both sites were accessible throughout the year and were in areas of running water.

2.3 *Pipestone National Monument*

PIPE comprises 115 ha in southwestern Minnesota. The soft red stone, Pipestone, quarried at in the Park, has been used for

ceremonial purposes by American Indians for over 400 years. Pipestone Creek flows approximately 1.2 km through the **PIPE**.

Aside from the Pipestone quarries, **PIPE** maintains 105 ha of native and restored prairie. It is located in Küchler's bluestem prairie region (Andropogon, Panicum, Sorghastrum) (Küchler 1964, Stubbendieck and Willson 1986), and Omernick's Northern Glaciated Plains ecoregion (Omernick 1987). The bedrock is Sioux Quartzite, a precambrian era rock.

Agriculture is the primary land use in the region around **PIPE**. There is a state game reserve (leased from the U.S. Fish and Wildlife Service) making up the northern boundary of the Park and the city of Pipestone borders **PIPE** on the south.

Pipestone Creek originates as a main county drainage ditch near Holland, Minnesota. The creek enters the Park over Winnewissa Falls, where it becomes a meandering stream. In the early 1900's the falls were blasted to lower them approximately 2.5 to 3 m in order to drain additional land for agricultural use for the nearby Indian School. The lowering of the falls changed the overall flow pattern of Pipestone Creek, greatly increasing siltation rates (Appendix D). Pipestone Creek flows into Hiawatha Lake (0.1 ha), a natural basin enlarged by construction of a dam. The dam was necessary to raise the lake level to accomodate the increased silt loads of the creek. The stream is subject to extreme flooding, with the stream often rising several meters in a 24 hour period. Considerable icing occurs commonly throughout the winter. The stream generally has a cobble/pebble substrate with areas of

exposed bedrock.

The fish and algae of Pipestone Creek have been previously surveyed. The fathead minnow (Pimephales promelas Rafinesque) and the creek chub (Semotilus atromaculatus (Mitchill)) were considered the two most common fish species by Schmidt (see Appendix C). Two fish species listed as threatened by neighboring states were found in Pipestone Creek within **PIPE**, the Topeka shiner (Notropis topoeka Gilbert) (Iowa) and the plains topminnow (Fundulus sciadicus Cope) (South Dakota) (in litt. Konrad Schmidt, 1988, **PIPE**). A survey of the algae (Appendix D) indicated at least 22 genera present in Pipestone Creek. Chara vulgaris and Cladophora were common during June 1989.

2.3.1 Study Sites

Two permanent sampling sites have been established on Pipestone Creek in **PIPE** for benthic macroinvertebrate sampling and water chemistry monitoring. Site 1 (PPS1) is a riffle about 30 m below Winnawassa Falls near a large willow tree. Site 2 (PPS2) is about 25 m below Lake Hiawatha in a riffle directly above the second stream crossing of the Circle Trail. Both sites were in riffles and are usually accessible throughout the year.

2.4 *Herbert Hoover National Historic Site*

HEHO was established in 1965 at the birthplace of the former President. **HEHO** comprises approximately 77 ha in eastern Iowa and is cut by the West Branch Wapsinonoc Creek. The management aim with regard to the natural features of the **HEHO** is to restore and maintain a landscape similar to that which existed during the

Hoover's childhood.

The Küchler vegetation type is a mosaic of bluestem prairie (Andropogon-Panicum-Sorghastrum) and oak-hickory forest (Quercus-Carya) (Küchler 1964, Stubbendieck and Willson 1986). **HEHO** is in Omernick's (1986) Western Corn Belt Plains ecoregion. In 1971 prairie plants were seeded South and West of the developed area of Park.

West Branch Wapsinonoc Creek is a very small creek, measuring < 1 m in width in most reaches and has been completely dry several times this century. The stream banks are steep, about 2 m high in the black loess soil. Periodically the creek overflows its banks during high precipitation events. The creek originates in hilly, cultivated land about 5 km north and west of the **HEHO**. A gallery forest of hardwoods border the creek throughout the Park. The creek probably receives most of its water from runoff, but may have some groundwater inputs. The stream shares several characteristics of most streams with agricultural lands in the watersheds, including heavy sediment and nutrient loads. Hydrology and channel morphology probably differ from the preagricultural historical period (Menzel et al. 1984). The stream also receives runoff from the neighboring town of West Branch.

2.4.1 Study Site

One study site was established in a riffle reach on West Branch Wapsononoc Creek east of Parkside Drive and south of the **HEHO** auxiliary parking lot. The study reach was just east of a silver maple which was east of a large cottonwood tree.

2.5 *George Washington Carver National Monument*

GWCA was established in 1953 at the site of the boyhood home of the renowned scientist. It encompasses 85 ha (210 acres) in Newton County in rural southwestern Missouri. A major goal of the **GWCA** is to restore and maintain environmental conditions similar to those that existed in the 1860's, the time of the active Carver farm.

Two small streams, Carver Branch and Harkins Branch, flow through the **GWCA**. Existing water quality problems and potential threats to water quality have recently been documented in reports to the National Park Service (Aley and Aley 1985, Boyt 1987) which are reviewed in section 3.3. Carver Branch originates approximately 3.5 km northeast of the **GWCA**, near the town of Diamond, and flows in a southwesterly direction until it joins Shoal Creek. The stream is perennial within **GWCA** boundaries, although the flow is often greatly reduced in the summer. The stream has a rocky substrate and a partial woody canopy throughout its length in **GWCA**.

There are several of springs within the **GWCA**, including some within the Carver Branch channel which contribute to the flow of Carver Branch (Aley and Aley 1985). Williams Spring, which is north of Carver Branch, was dammed to form a small pond. From the pond a small creek, known as Williams Branch, flows for about 300 m before emptying into Carver Branch. Both springs served as sources of drinking water for farm families in Carver's time (Boyt 1986). Aley and Aley (1985) indicated that the springs within the

GWCA are part of a "spring complex," a series of springs with hydrologic interactions, that extends north and east of the Park.

The second stream, Harkins Branch, cuts through the northwest corner of the Park, with about 400 m of its length on Park property. It joins with Carver branch shortly after leaving the west **GWCA** boundary. Harkins Branch originates north of the **GWCA** and flows through a dairy operation just above the **GWCA**. The stream has a rocky bottom but the rocks are covered with sediment.

The surface waters of the **GWCA** are part of the Arkansas River watershed. The average annual precipitation is approximately 16 cm (USGS 1986). **GWCA** is located in the Ozark Plateau physiographic province and the Ozark aquifer system underlies the region. There are numerous springs, caves and sinkholes in the karst bedrock. There are complicated interactions between surface and groundwater flows and the region is therefore susceptible to groundwater contamination (USGS 1988).

The Küchler potential natural vegetation of the **GWCA** is a mosaic of bluestem prairie (<u>Andropogon</u>-<u>Panicum</u>-<u>Sorghastrum</u>) and oak-hickory forest (<u>Quercus</u>-<u>Carya</u>) (Küchler 1985, Stubbendieck and Willson 1986). Today, forested areas primarily occur near the streams in the Park. Prairie, agricultural, and developed areas make up the other parts of the **GWCA**. Prairie restoration is ongoing in several management units.

Grazing, cereal and row crops predominate outside the Park. The small town of Diamond is located northeast of the **GWCA** in the upper watershed of Carver Branch. An abandoned lead-zinc mine

exists southeast of the **GWCA**.

2.5.1 Study Sites

In June 1989, two macroinvertebrate sampling sites within the **GWCA** were established for this study, one on Carver Branch ("Carver") and one on Williams Branch ("Williams"). Carver and Williams are easily accessible from the visitor's trail. Carver is located in the riffle about 20 m downstream of the visitor's trail crossing Carver Branch. The Williams riffle reach is the area between the two trail crossings of Williams Branch. Water chemistry samples were obtained from these sites and one additional site on Harkins Branch ("Harkins"). Harkins is located on Harkins Branch at the west boundary of the **GWCA**.

2.6 *Wilson's Creek National Battlefield*

Wilson's Creek National Battlefield (**WICR**) is a 709 ha preserve located in southwestern Missouri (National Park Service 1976). It was authorized by Congress in 1960 to commemorate a pivotal Civil War battle that was fought 10 August 1861. The city of Springfield is 16 km to the northeast. Wilson Creek meanders from north to south for about 4.8 km through the center of the battlefield. Wilson Creek averages about 9 - 11 m wide and has a normal flow of 1.8 - 2 m^3/s (National Park Service 1976). The creek enters the James River 1.6 km south of **WICR**. Skeggs Branch, a tributary, joins Wilson Creek near the center of the Park. The headwaters of Wilson Creek are in Springfield (pop. 134,000) and the headwaters of Skeggs Branch are near the town of Republic (pop. 4500) to the west of the **WICR**. These streams are part of the James

River basin which drains the Springfield Plateau region of the Ozark Highlands.

The natural vegetation of the area is a mixture of oak-hickory forest and bluestem prairie (Küchler 1964, Stubbendieck and Willson 1986). The area is probably less forested today than during the time of the battle, when accounts of the battle suggested the occurrence of mature oak-hickory forest (Landers 1975). The river corridors today are thickly forested which apparently represents their historical condition. There are prairie areas in good condition but invasion of exotic woody species is a problem; management and prairie restoration of these and other areas is ongoing (Landers 1975, Stubbendieck and Willson 1986). The area is part of Omernick's (1986) Ozark Highlands ecoregion which is topographically characterized by open and high hills. Land use in the area is cropland, pasture, woodland, and forest.

Water quality of Wilson Creek (sometimes referred to as Wilsons Creek, or Wilson's Creek) and Skeggs Branch (also known as Schuyler Creek) has been a concern of the National Park Service for several years. Point source pollution from the Springfield Southwest Wastewater Treatment Plant (SWTP) has been implicated in degraded water quality of Wilson Creek (Aley and Aley 1988). During low flow conditions 75% of Wilson Creek water is derived from the SWTP (Aley and Aley 1988). Wastewater effluent has been implicated for conditions such as low aquatic insect diversity, bacterial composition, oxygen depletion, fish kills, and sludge deposits on the stream substrate (Cook 1984). Resuspension of

sewage sludge after storm events has been cited as a cause for these conditions (Aley and Aley 1988). Upgrade from secondary to tertiary treatment at the SWTP was implemented in 1976 (Cook 1984).

Recently, in October 1989, Nimmo et al. (1990) conducted acute and chronic Ceriodaphnia toxicity tests in water from sites in the Wilson Creek watershed above and below the SWTP. In chronic tests they found toxicity in sites below the treatment plant. They also reviewed (Finger and Crawford 1987) evidence of high copper and zinc concentrations originating from plant effluent.

Hydrologically the region is complex because of the fractured and jointed karst topography. Aley and Aley (1988) reported on the hydrology of the waters of and around **WICR**. Groundwater traces indicated sewage contamination of both Wilson Creek and Skeggs Branch. They reported on four non-point sources of water contamination in the Wilson Creek watershed which may impact the waters of **WICR**: (1) septic fields, (2) land disposal of municipal wastewater treatment sludges, (3) pesticide and PCB contamination, (4) urban stormwater runoff.

2.6.1 Study Sites

Three study sites, Wilson Upper, Wilson Lower, and Skeggs, were established within the boundaries of Wilson's Creek National Battlefield. Wilson Upper and Wilson Lower were located on Wilson Creek. Wilson Upper was located north of the bridge where the visitor's road first crosses Wilson Creek. The site was approximately 0.4 km from where the creek enters the National Battlefield. Wilson Lower was about 25 m south of the visitor road

bridge at the second crossing of the creek. Skeggs was located on Skeggs Branch where the branch enters the western boundary of the National Battlefield, 10 m from the Road ZZ bridge. All sites were in riffle stretches. Riffles typically contain the greatest density and diversity of benthic macroinvertebrate taxa in lotic systems and can be sampled efficiently (Cummins 1962, Platts et al. 1983).

3.0 WATER CHEMISTRY AND PHYSICAL CHARACTERISTICS

Chemical characteristics of water depend primarily on local geology and climate (Reid and Wood 1976) and secondarily on the type and condition of terrestrial vegetation within a watershed. The physical environment and chemistry of surface waters determines in great part the species within the aquatic ecosystem. In turn, biological activity affects the chemical and physical environment. Alteration of one aspect may lead to changes in other components of the aquatic ecosystem.

There are both short- and long-term effects of water quality changes. Long-term effects include stresses on individuals that make them less able to survive, grow, reproduce, or cause an unfavorable behavioral change. Also, reactions among various water quality components must be recognized. Increased water temperature, for example, lowers the ability of water to hold oxygen; pH affects the solubility and biological activity of many chemicals. Additionally, chemical and physical characteristics vary during the day and among microhabitats within the stream, and alteration of this variation may be detrimental to aquatic life.

The goal of our chemical and physical analysis of the streams in this study was to acquire baseline data for the physical aquatic ecosystems of the park units. These data can be used with future biological surveillance or monitoring, be compared with other sites in the region and with water quality standards, and useful for identify areas of concern.

Although comparisons are made with established chemical water quality criteria, such as the U.S. Environmental Protection Agency's (1976) criteria for water quality, these criteria should only be used as a general guide. They do not reflect the requirements of all organisms that reside in every ecosystem, because vast local and regional differences exist in natural water chemistry and biological communities. The data in this study are intended to summarize the range of conditions that exist, longitudinally and seasonally in the National Park Service units.

3.1 *Methods*

Surface water samples were taken and measures in the field were made along with collection of benthic macroinvertebrate samples. At each site, temperature and pH were measured in the field for five park units and at **AGFO** dissolved oxygen and discharge was also measured. Water temperature was measured in the field with a long-stem thermometer. The pH was measured using Hellige comparator with phenol red indicator. Both water temperature and pH measures were obtained from water near the shore to prevent unnecessary disturbance of the stream bottom.

At **AGFO** dissolved oxygen was measured in the field with a Yellow Springs Instrument Co., Inc., Model 54A Oxygen Meter and discharge. In order to assess any notable changes in stream flow through the **AGFO**, discharge was calculated at Sites 1 (near the river's entry into the **AGFO**) and 3 (near the river's exit from the **AGFO**). Current velocity was measured with a Price AA flow meter.

Discharge was calculated by the six-tenths depth method (Buchanan and Somers 1969, Platts et al. 1983).

Water surface samples were obtained by wading into the stream and filling water bottles by leaning upstream and dipping the sample bottle into the water. Parameters included total phosphorus, total kjeldahl nitrogen, nitrate-nitrogen, ammonia-nitrogen, total organic carbon and alkalinity. Total phosphorus and total organic carbon samples were preserved with sulfuric acid at a concentration of 2 ml/l. The water samples were taken before benthic sampling and downstream of the benthic sampling areas. The samples were placed on ice and returned to the Colorado State University Soil Testing Laboratory for analysis. The analytical methods used are presented in Table 3-1. During the first sampling year at **AGFO** one bottle of surface water was sampled with no preservative. This year parameters measured included total phosphorus, total kjeldahl nitrogen, nitrate-nitrogen and hardness.

At **AGFO** only seston was collected with a hand pump at several intervals across transects at sites 1 and 3. A volume of 100 l was passed through a sieve set to obtain three size fractions. The seston divided into three size fractions: coarse (CPOM, < 1 mm), fine (FPOM, < 1 mm and > 0.063 mm), and ultrafine (UPOM, < 0.063 mm). Samples were analyzed for organic carbon at the Colorado State University Soil Testing Laboratory for analysis (Table 3-1).

At **AGFO** a U.S.G.S. surface water gaging station is located approximately 100 m west of the bridge on State Highway 29, near

Table 3-1. Methodology used for water chemistry analysis at Soil Testing Laboratory, Colorado State University, Fort Collins, Colorado. Abbreviations: USEPA, U.S. Environmental Protection Agency; APHA, American Public Health Association; ICP, Inductively Coupled Plasma Atomic Emission Spectrometer.

Total Phosphorus	-	H_2SO_4-$K_2S_2O_8$ digestion, ICP, APHA et al. (1989) Method 4500-P B-5
Total Kjeldahl Nitrogen (TKN)	-	H_2SO_4 - $CuSO_4$ digestion, colorimetric, automated phenate, USEPA (1983) Method 351.1
Nitrate-Nitrogen (NO_3-N)	-	Ion chromatography, USEPA (1984) Method 300.0. Also checked with USEPA (1983) Method 353.2 except use Zn reduction
Ammonia-Nitrogen (NH_4-N)	-	Colorimetric, automated phenate, USEPA (1983) Method 350.1
Hardness	-	Ca and Mg by ICP, USEPA (1983) Method 200.7
Calcium	-	Samples filtered through 0.45μm membrane filters; analysis by ICP, USEPA Method 200.7
Magnesium	-	same as Ca
Alkalinity	-	Gran titration
Periphyton (Aufwuchs)	-	Dry wgt. - dry sample at 105°C Ash wgt. - ash residues at 550°C in muffle furnace
UPOM, Total Organic Carbon	-	Wet chemical oxidation USEPA (1983) Method 415.1 and persulfate oxidation USEPA (1983) Method 415.2
FPOM, CPOM	-	Wet oxidation-diffusion (Snyder and Trofymow 1984)

the west border of the **AGFO**. Discharge data is available from water year 1958 to the present. This data was examined to characterize the Niobrara River stream flow and determine trends over time. All regression analysis was performed using the PC SAS Procedure REG (SAS 1988).

Only at **AGFO**, periphyton production (Aufwuchs accrual) was estimated in the first year of the study. Plexiglass hemispheres 5 cm in diameter were attached to the bottom substrate in the main portion of the stream by means of 18-cm spikes. The colony forming on the top surface was removed and ash-free dry weight determined according to the procedures in Vollenweider (1971) at the Colorado State University Soil Testing Laboratory.

3.2 *Description of Parameters*

3.2.1 Temperature

Life histories of much aquatic life depends on the water temperature and its variation (diel, microhabitat, and seasonal), consequently temperature is a regulating or limiting factor in aquatic systems (Reid and Wood 1976, Ward 1991). Invertebrates and fish are poikilothermic, having limited internal temperature regulation, therefore life cycles are expectedly dependent on the external temperature regime. Species are classified as stenothermic, adapted to a narrow range of temperature, or eurythermic, tolerant to a broad temperature range. Typical life cycle factors that respond to temperature include egg maturation, adult fecundity, growth and maturation. Additionally, temperature elicits behavioral responses, and on a community level influences

trophic relations and species diversity (see review of Ward and Stanford 1982). Other water quality parameters are also affected by temperature, notably dissolved oxygen. Large scale water temperature changes are caused by large dams and power plant discharge. Changes in riparian vegetation or changes in stream discharge also influence water temperature.

3.2.2 Hydrogen Ion Activity (pH)

Hydrogen ion activity is the concentration of hydrogen ions and is expressed as pH (*potentia hydrogenii*), with a range of 1-14 (Cole 1979). At pH 7 the molar concentration of hydrogen is 10^{-7}M. An increase in hydrogen ions results in a lowering of the pH. Hydrogen ion activity is dependent on alkalinity (see section 3.2.5). The natural pH of a stream is determined primarily by the chemical composition of the substrate, current, and biological processes (Reid and Wood 1976). The U.S. EPA (1976) water quality criteria for pH range for freshwater aquatic life is 6.5 - 9.0. The solubility and toxicity of other compounds is affected by changes in pH (U.S. EPA 1976).

3.2.3 Dissolved Oxygen

Oxygen is essential to all aerobic life, and therefore is one of the fundamental parameters of aquatic ecosystems. Dissolved oxygen in water is supplied by the atmosphere and photosynthetic plants and varies diurnally (Voshell and Hiner 1990). Oxygen solubility is inversely related to water temperature. Biochemical reactions, such as the oxidation of ammonia, are dependent on the concentration of dissolved oxygen (U.S. EPA 1976). The U.S. EPA

(1976) water quality criteria for concentration of dissolved oxygen is a minimum of 5.0 mg/l.

3.2.4 Total Phosphorus

Phosphorus occurs in various forms of phosphate (broad categories include: orthophosphate, condensed phosphate, and organic phosphate) in natural waters. Natural sources of phosphorus in water include the leeching of rock minerals and release from sediments (Hem 1985). Phosphorus, along with nitrogen, is a main limiting factor for primary productivity in a body of water. Over enrichment of nutrients can cause excessive algal and plant growth in a lentic or lotic system. Meybeck (1982) estimated that the worldwide average of naturally occurring total dissolved phosphorus in rivers averages 0.025 mg/l. The U.S. Council on Environmental Quality (CEQ 1975) suggested a maximum "benchmark" level of 0.03 mg/l phosphorus for protection of aquatic life, though regional or local concentrations may be much lower. Phosphorus is a major element in agricultural fertilizers which enter streams through surface water runoff. It is also a component of municipal and domestic wastewater, and animal wastes.

3.2.5 Total Kjeldahl Nitrogen (TKN), Nitrate-Nitrogen (NO_3-N), Ammonia-Nitrogen (NH_4-N)

Nitrogen occurs in various states (nitrate, nitrite, ammonia, and organic nitrogen) in natural waters. As with phosphorus, excess nitrogen is a cause of eutrophication. Nitrate is the form that is most often utilized by higher plants. A widely used criterion for drinking water quality is a maximum of 10 mg/l NO_3-N

(U.S. EPA 1976). The U.S. Council on Environmental Quality (CEQ 1975) suggested a maximum "benchmark" level of 0.6 mg/l nitrate-nitrogen for protection of aquatic life. High concentrations of nitrate in water have been attributed to livestock waste, fertilizer leaching, and municipal and domestic sewage. Kjeldahl nitrogen is a measure of organic nitrogen plus ammonia nitrogen, therefore, the difference of kjeldahl nitrogen and ammonia nitrogen yields organic nitrogen (American Public Health Association et al. 1989). The un-ionized form of ammonia, NH_3, is known to be toxic to freshwater aquatic life in high concentrations. The toxicity of ammonia is dependent on pH, as well as on other factors like temperature, because the hydrogen ion concentration governs the transition of NH_4^+ to the toxic form NH_3(U.S. EPA 1976). In a tallgrass prairie stream lower nitrogen concentrations occurred in the late spring and summer when terrestrial vegetation was growing (McArthur et al. 1985).

3.2.6 Alkalinity

Alkalinity, or buffering capacity, is a measure of the ability of a solution to neutralize acid, and serves as an index of how sensitive a water body is to acidic deposition or any acid source. Dissolved carbon dioxide species, bicarbonate and carbonate, are the main contributors to alkalinity in natural waters, although noncarbonate sources may contribute. Carbon dioxide concentration in the atmosphere and in the soil are the principal sources of alkalinity in most natural systems (Hem 1985). Underlying geological formations and their degree of weathering influence

alkalinity (Cole 1979). Alkalinity is responsible for much of the overall chemical environment because it is a major variable controlling the form, concentration, biological availability, and toxicity of many ions as well as the hydrogen ion activity (Feldman and Connor 1985). Alkalinity was evaluated by the gran titration method.

3.2.7 Hardness

The concentration of polyvalent metal cations determines water hardness. It is measured by the amount of Ca^{2+} and Mg^{2+} ions expressed as an equivalent mass of calcium carbonate ($CaCO_3$). Water is usually referred to by the relative terms "soft" and hard." Durfor and Becker (1964) use the following classification:

Hardness range (mg/l of $CaCO_3$)	Description
< 60	Soft
61-120	Moderately hard
121-180	Hard
> 180	Very hard

Some groups of invertebrates appear indifferent to water hardness, but to others it is important. For example, organisms that secrete calcium carbonate shells, such as many Crustacea and Mollusca, are typically more common in hard waters (Hynes 1970).

3.2.8 Carbon (total organic carbon)

Sources of carbon in natural waters are both allochthonous and autochthonous. Allochthonous inputs include direct input of leaves and other organic matter, and indirect input from soil organic matter by overland flow and shallow groundwater flow.

Autochthonous sources include extracellular excretion and cellular debris (from algae and macrophytes) (Lush 1981). Various organic carbon fractions are measured to assess the detrital food resources in water.

The River Continuum Concept (RCC) (Vannote et al. 1980) provides a model of stream organization in which organic matter is processed along a longitudinal (downstream) profile, and to which streams may be compared. The RCC was developed for streams which have large amounts of leaf litter input (Coarse Particulate Organic Matter (CPOM)) in canopied headwaters, and therefore, energy input is allochthonous in the headwaters. Downstream, the relative canopy cover decreases and energy input is increasingly autochthonous as more solar radiation reaches the benthic substrate, and as photosynthesis increases within the stream. Matthews (1988) discusses two major differences between prairie streams and the RCC model. First, the headwaters of prairie streams are usually open to sunlight and often downstream; even today, gallery forest provides a canopy. Second, whereas the RCC stream derives much of its allochthonous organic matter from leaf litter, prairie streams receive grass litter inputs (Gurtz et al. 1982) and detritus from grasslands.

Seston is the particulate matter, organic and inorganic, suspended in the water column. The first sampling season at **AGFO** seston was evaluated as organic carbon and separated into three size fractions: coarse particulate organic matter (< 1 mm, CPOM), fine particulate organic matter (< 1 mm and > 0.063 mm, FPOM), and

ultrafine particulate organic matter (< 0.063 mm, UPOM). Various organic carbon fractions are measured to assess the detrital food resources in water.

3.2.9 Discharge

Discharge, or streamflow, is the volume of water moving past a cross section of a stream per unit time. Streamflow is a characteristic physical attribute of lotic systems that influences habitat structure (Leopold et al. 1964, Hynes 1970). Flow regime influences community structure (Poff and Ward 1989) and there is an interrelationship between vegetation cover and flow regime (Gregory and Gurnell 1988).

3.2.10 Periphyton (Aufwuchs)

Periphyton growing on a variety of substances forms an important photosynthetic energy source in stream ecosystems and constitutes the principal algal community in stream ecosystems (Goldman and Horne 1983). Periphyton production has been employed as an index to estimate the comparative fertility of polluted and unpolluted waters (Vollenweider 1971). Because the periphyton community is difficult to quantitatively sample *in situ*, several investigators recommend the use of artificial substrates, especially those composed of transparent material (Schwoerbel 1970, Vollenweider 1971). Aufwuchs is the community of aquatic organisms and associated detritus that form a coating on submerged objects, of which periphyton often comprises a large part.

3.3 *Summary of Chemistry and Physical Analyses*

3.3.1 Agate Fossil Beds National Monument

The Niobrara River (through **AGFO**) is a perennial groundwater supplied stream. The flow is consistent with few flood or low water events. This contrasts it to many prairie streams which characteristically have large fluctuations (Matthews 1988). Water chemistry values are presented in Table 3-2. The concentrations of total nitrogen and phophorus are relatively low compared to most streams indicating that few nutrients are being added. All summer measures of phosphorus were < 0.01 mg/l, and most other measures were below the CEQ (1975) benchmark of 0.03 mg/l. Phosphorus levels in the Niobrara within the **AGFO** were low indicating minimal agricultural runoff at this time. The pH of the river through the **AGFO** was slightly alkaline. This is a characteristic of most unpolluted streams and is considered a favorable condition for aquatic life (Reid and Wood 1976). Dissolved oxygen levels demonstrate that oxygen was available and usually near saturation. According to the Durfor and Brecker (1964) classification Niobrara water is considered "hard".

The organic carbon concentrations are low for a range of streams but within that is expected for the prairie grassland region (Ford et al. 1990). Typically, natural waters will have concentrations of organic carbon from 0.1 to 10 mg/l (Stumm and Morgan 1970). At **AGFO** total organic carbon measures were around 4 mg/l, and the lowest total organic carbon concentration was found in the winter (Table 3-2). The UPOM fraction had the greatest

Table 3-2. Water chemistry values, Agate Fossil Beds National Monument, Nebraska: Water temperature (Temp.), pH, dissolved oxygen (DO), total phosphorus (Total P), Total kjeldahl nitrogen (TKN), nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_4-N), hardness as $CaCO_3$ (Hardness), Calcium (Ca), magnesium (Mg), gran alkalinity (Alkalinity), and total organic carbon (TOC) for Sites 1, 2, and 3.

Site 1

Date	Total P (mg/l)	TKN (mg/l)	NO3-N (mg/l)	NH4-N (mg/l)	Hard. (mg/l)	Ca (mg/l)	Mg (mg/l)	Temp (°C)	pH (mg/l)	DO (mg/l)	Alk (µeq/l)	TOC (mg/l)
16-VI-88	0.00	0.5	0.1	--	198	--	--	23	7.7	7.8	--	--
30-VI-88	0.02	0.5	1.2	--	165	49.1	10.2	17	7.8	7.4	--	--
14-VII-88	0.00	0.7	1.1	--	158	45.3	10.9	24	7.9	7.3	--	--
28-VII-88	0.00	0.0	1.3	--	162	47.4	10.6	22	7.9	7.4	--	--
11-VII-88	0.00	0.2	1.2	--	164	--	--	20	7.9	8.4	--	--
25-VIII-88	0.00	0.0	1.1	--	161	--	--	19	8.0	8.6	--	--
16-IX-88	0.00	0.0	1.4	--	175	--	--	14	7.8	--	--	--
16-X-88	0.00	0.0	1.7	--	175	--	--	11	8.0	9.1	--	--
21-II-89	0.00	0.0	0.9	--	175	--	--	--	--	--	--	--
18-III-89	0.01	0.1	1.1	--	167	--	--	3	8.2	13.0	--	--
12-VI-89	0.02	0.2	0.9	0.06	--	--	--	17	8.1	7.4	4555	3.5
16-IX-89	0.04	0.1	1.4	0.02	--	--	--	14	8.0	9.0	6797	4.4
3-I-90	0.07	0.6	2.2	0.14	--	--	--	1	7.8	12.6	3810	2
31-III-90	0.01	0.5	0.7	0.20	--	--	--	9	8.1	9.1	4088	4.6
Mean	0.01	0.2	1.2	0.03	121	10.1	2.3	14	7.4	7.6	1375	1.0

Site 2

Date	Total P (mg/l)	TKN (mg/l)	NO3-N (mg/l)	NH4-N (mg/l)	Hard. (mg/l)	Ca (mg/l)	Mg (mg/l)	Temp (°C)	pH (mg/l)	DO (mg/l)	Alk (µeq/l)	TOC (mg/l)
16-VI-88	0.00	0.4	1.6	--	198	--	--	25	7.7	10.4	--	--
30-VI-88	0.02	0.5	1.4	--	148	43.8	9.3	18	7.8	7.0	--	--
14-VII-88	0.00	0.5	1.7	--	161	46.0	11.1	24	7.8	7.1	--	--
28-VII-88	0.00	0.0	1.8	--	145	42.7	9.4	23	7.9	8.3	--	--
11-VII-88	0.00	0.1	1.9	--	160	--	--	20	8.2	7.6	--	--
25-VIII-88	0.00	0.0	1.5	--	158	--	--	18	7.8	9.2	--	--
16-IX-88	0.00	0.0	1.8	--	172	--	--	15	8.2	--	--	--
16-X-88	0.00	0.0	2.5	--	173	--	--	10	8.0	9.8	--	--
21-II-89	0.01	0.0	1.0	--	173	--	--	--	--	--	--	--
Mean	0.00	0.2	1.7	--	165	14.7	3.3	17	7.0	6.6	--	--

Site 3

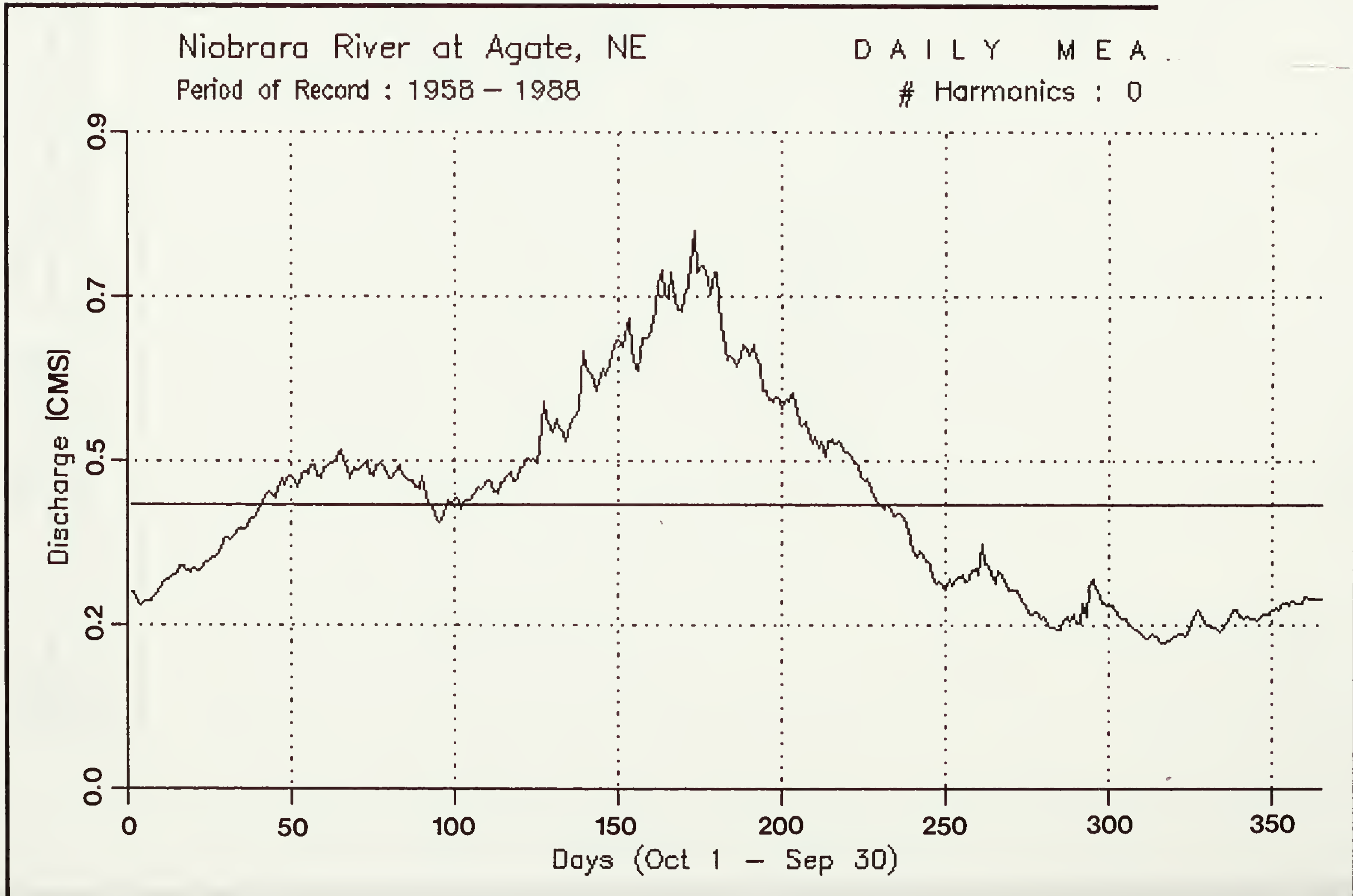
Date	Total P (mg/l)	TKN (mg/l)	NO3-N (mg/l)	NH4-N (mg/l)	Hard. (mg/l)	Ca (mg/l)	Mg (mg/l)	Temp (°C)	pH (mg/l)	DO (mg/l)	Alk (µeq/l)	TOC (mg/l)
16-VI-88	0.00	0.5	1.6	--	196	--	--	22	8.0	8.6	--	--
30-VI-88	0.02	0.5	1.7	--	157	46.4	9.8	17	8.1	7.3	--	--
14-VII-88	0.00	0.4	1.6	--	164	47.2	11.2	24	8.0	7.3	--	--
28-VII-88	0.00	0.0	1.6	--	154	45.5	9.9	21	8.3	6.7	--	--
11-VII-88	0.00	0.0	1.5	--	172	--	--	21	8.1	7.9	--	--
25-VIII-88	0.00	0.0	1.4	--	162	--	--	17	8.2	8.6	--	--
16-IX-88	0.00	0.0	1.8	--	179	--	--	14	8.4	--	--	--
16-X-88	0.00	0.0	2.4	--	172	--	--	9	8.5	9.5	--	--
21-II-89	0.00	0.0	1.0	--	172	--	--	--	--	--	--	--
18-III-89	0.01	0.0	1.0	--	163	--	--	2	8.3	12.1	--	--
12-VI-89	0.02	1.5	0.7	0.09	--	--	--	18	7.8	6.2	6100	4.2
16-IX-89	0.04	0.4	1.9	0.07	--	--	--	14	8.1	9.0	6428	4.2
31-III-90	0.01	0.4	0.8	0.20	--	--	--	8	8.1	8.4	4174	4.4
Mean	0.01	0.3	1.5	0.03	130	10.7	2.4	14	7.5	7.0	1285	1.0

concentration of organic carbon in this study (Table 3-3). FPOM and CPOM fractions seemed to have the highest volume sampled at the beginning of the summer.

Above Site 1, the location of the U.S.G.S. gaging station, the Niobrara River drains approximately 2200 km^2 (840 mi^2). The average discharge from 1957-1985 was 0.394m^3/s (13.9 ft3/s or 10,070 acre-ft/yr) (Hydrodata 1989). Peak flows occur February through April and the lowest flows are July through September (Fig. 3-1). The peak flow periods are also the time when the greatest year to year variance of flow occurs (Fig. 3-2). The low variance during periods of low flow indicates that discharge is maintained by groundwater inputs. Discharge measurements obtained in this study did not indicate any noticeable difference in discharge between Sites 1 and 3 (Fig. 3-3).

Discharge data over the last 30 years indicate that stream flow has decreased in the Niobrara River (Fig. 3-4). A negative slope was found when yearly total flow data was regressed versus water years 1958-1988 ($t = -3.6$, $p = 0.001$). In order to determine when flow was decreasing, monthly average discharge was regressed against water year. Over the period of record, flow decreased (significant, $p < 0.05$, negative slope in regression line) in November, December, January, and February (Table 3-4). In these months there is no irrigation in the watershed. Thus, the reduction in flow may be attributable to lowering of groundwater levels or reduction groundwater recharge within the watershed.

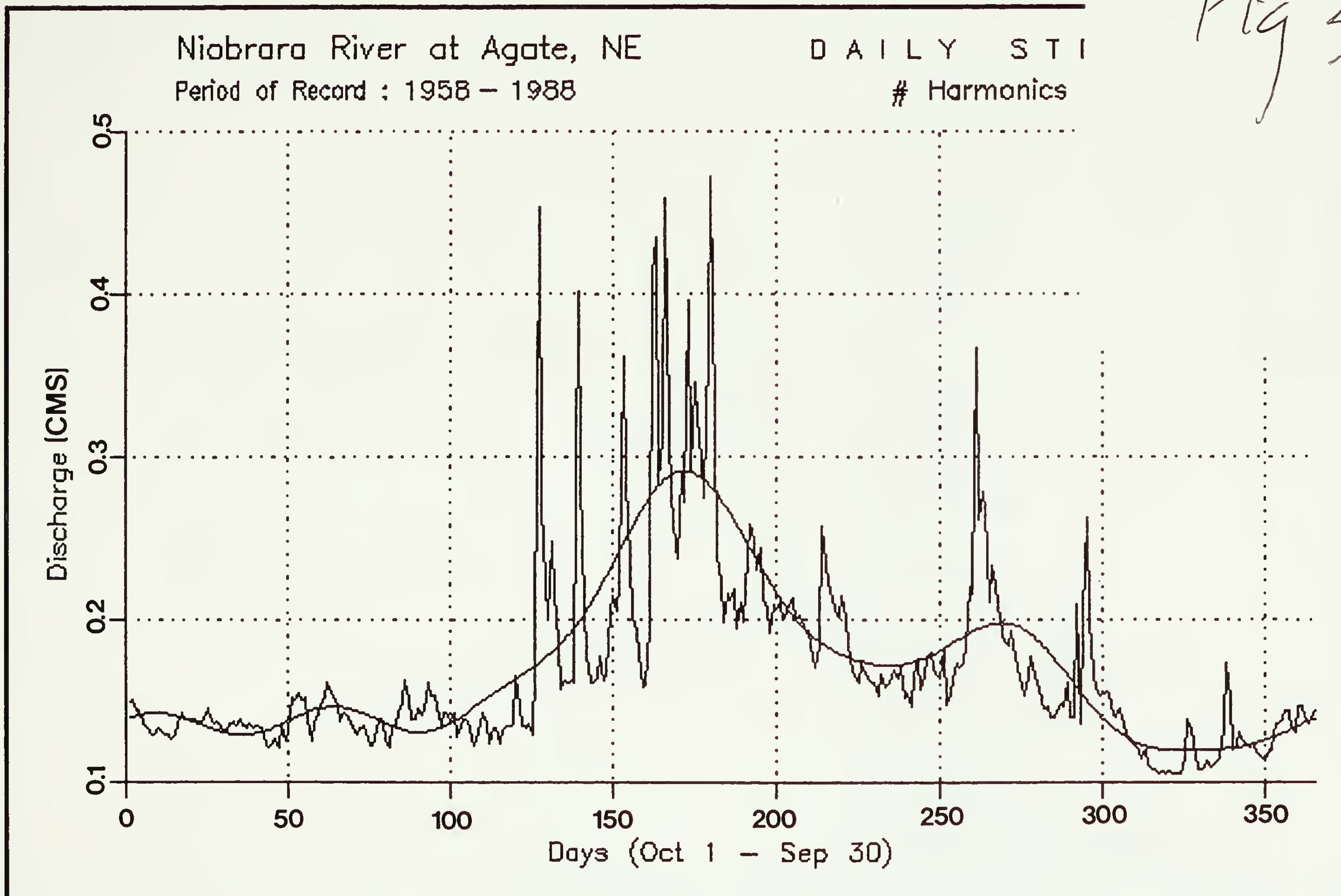
Fig 3-1



Niobrara River at Agate, NE
Period of Record : 1958 – 1988
D A I L Y M E A
Harmonics : 0
Discharge (CMS)
0.0
0.2
0.5
0.7
0.9
0
50
100
150
200
250
300
350
Days (Oct 1 – Sep 30)

Figure 3-1. Daily mean discharge (cubic meters/second) for each da (October 1 - September 30) over the period 1958-1988 at U.S.G.S. surface 06454100 at Agate Fossil Beds National Monument, Nebraska. Straight flow.

Fig 3-2



Niobrara River at Agate, NE
Period of Record : 1958 – 1988
D A I L Y S T I
Harmonics
Discharge (CMS)
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250
300
350
Days (Oct 1 – Sep 30)

Figure 3-2. Daily standard deviation of discharge for each day of the 1 - September 30) over the period 1958-1988 at U.S.G.S. surface water gag at Agate Fossil Beds National Monument, Nebraska. Smooth line was fit by seven harmonics.

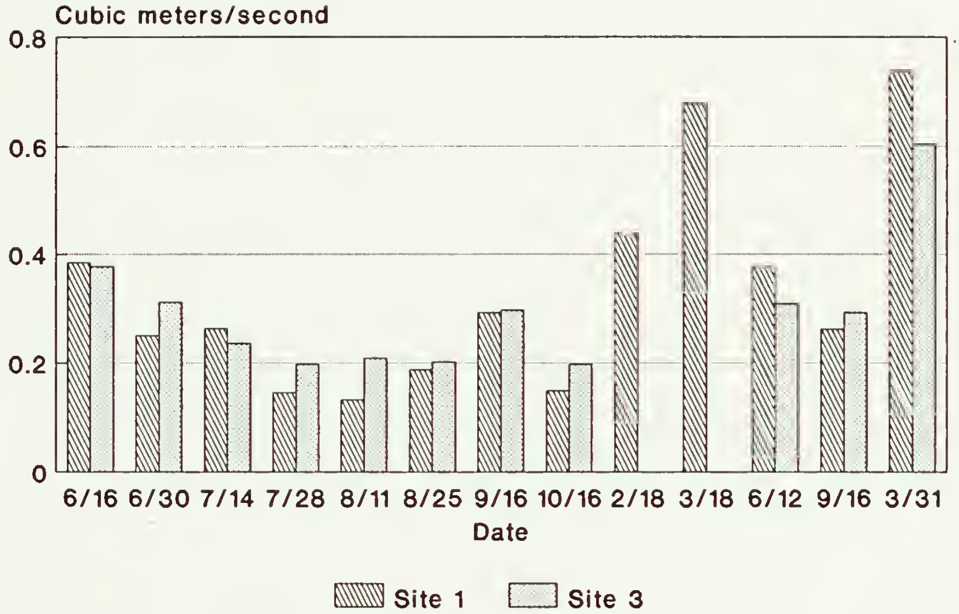

Cubic meters/second
0.8
0.6
0.4
0.2
0
6/16 6/30 7/14 7/28 8/11 8/25 9/16 10/16 2/18 3/18 6/12 9/16 3/31
Date
Site 1
Site 3

Fig 3-3

Figure 3-3. Discharge measures at Sites 1 and 3, Agate Fossil Beds National Monument, Nebraska, includes sampling dates June 1988 to March 1990.

Figure 3-4. Niobrara River discharge at Agate Fossil Beds National Monument, Nebraska, water years 1958-1988. Expressed as specific flow in mm. Specific flow is calculated by dividing the total volume of water that flows past a point in the river, by the drainage area of the river at that point.

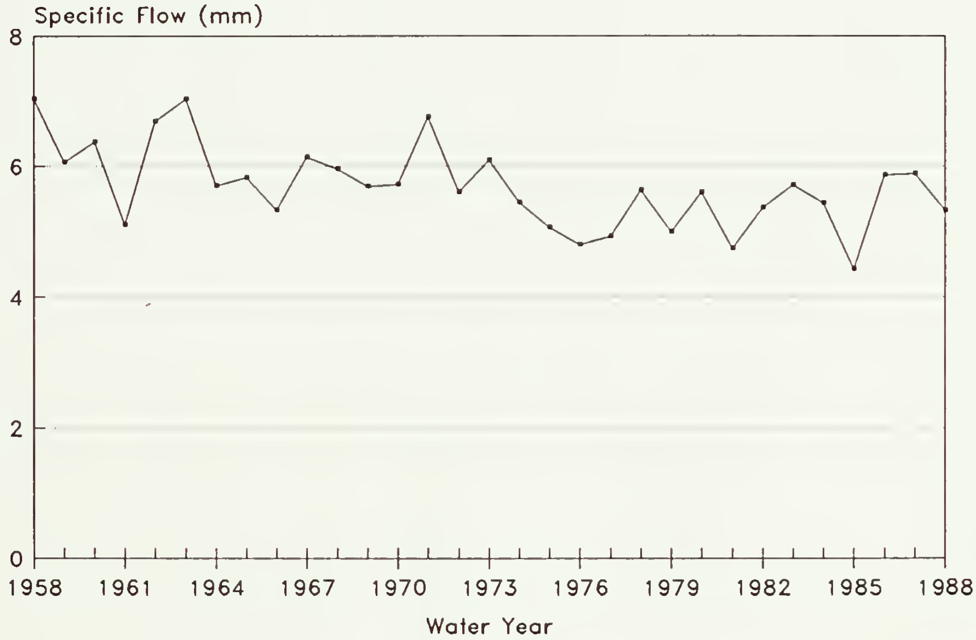


Figure 3-4. Niobrara River discharge at Agate Fossil Beds National Monument, Nebraska, water years 1958-1988. Expressed as specific flow in mm. Specific flow is calculated by dividing the total volume of water that flows past a point in the river, by the drainage area of the river at that point.

Table 3-3. Seston data, Agate Fossil Beds National Monument, Nebraska. A) Seston fractions (coarse particulate organic matter (< 1 mm, CPOM), fine particulate organic matter (< 1 mm and > 0.063 mm, FPOM), and ultrafine particulate organic matter (< 0.063 mm, UPOM)) expressed as mg organic carbon/l. B) Dry weight of FPOM and CPOM fractions retained in 100 l of river water, and percent carbon of the fractions.

A)

	Site 1			Site 3		
Date	UPOM	FPOM	CPOM	UPOM	FPOM	CPOM
16-VI-88	3.7	0.31	0.01	2.9	0.55	0.00
30-VI-88	12.6	0.73	0.06	2.7	1.20	0.05
14-VII-88	3.1	0.42	0.01	3.9	0.30	0.03
28-VII-88	15.9	0.06	0.00	3.9	0.21	0.00
11-VIII-88	2.4	0.03	0.00	1.0	0.07	0.00
25-VIII-88	0.6	0.02	0.00	1.6	0.02	0.00
16-IX-88	1.4	0.00	0.00	1.7	0.03	0.00
18-X-88	1.7	0.02	0.00	1.4	0.03	0.00
18-II-89	1.9	0.02	0.00	1.1	0.00	0.00
12-VI-89	2.4	--	--	2.6	--	--
16-IX-89	2.9	0.11	0.00	5.2	0.05	0.01
03-I-90	2.0	0.01	0.00	--	--	--
31-III-90	3.3	0.00	0.00	4.3	0.00	0.00

B)

	Site 1				Site 3			
	FPOM		CPOM		FPOM		CPOM	
Date	Dry Wgt. (mg)	%C	Dry Wgt. (mg)	%C	Dry Wgt. (mg)	%C	Dry Wgt. (mg)	%C
16-VI-88	350.0	8.9	2.7	25.5	720.0	7.7	1.2	18.2
30-VI-88	14700.0	0.5	324.6	1.7	10010.0	1.2	14.2	32.3
14-VII-88	11119.8	0.4	491.3	0.2	884.6	3.4	19.0	13.8
28-VII-88	89.8	7.0	6.5	0.0	470.6	4.4	6.0	0.0
11-VIII-88	114.4	2.8	12.4	0.0	57.8	11.3	7.6	0.0
25-VIII-88	83.8	2.6	23.6	0.0	26.0	7.7	7.8	0.0
16-IX-88	13.8	0.0	9.1	0.0	29.4	9.9	10.3	0.0
18-X-88	50.4	3.7	8.0	0.0	45.7	5.9	18.8	0.0
18-II-89	60.5	3.0	3.7	10.0	2.5	0.0	1.1	2.0
12-VI-89	51.8	--	6.1	--	349	--	6.7	--
16-IX-89	49.8	22.0	2.8	15.0	20.5	23.0	4.0	13.0
03-I-90	38.8	2.0	0.0	0.0	--	--	--	--
31-III-90	0.7	0.0	196.0	0.0	0.3	0.0	9.3	0.0

Table 3-4. Results of regression analysis of average monthly flow of Niobrara River at Agate Fossil Beds National Monument, Nebraska, over period 1958-1988. Slope indicates whether slope of regression line was positive or negative. Asterisk indicates significant slope, $p < 0.05$, 'ns' indicates not significant, $p > 0.05$.

Month	Slope	t	p	
January	-	-5.2	< 0.001	*
February	-	-2.5	0.02	*
March	-	-0.9	0.37	ns
April	-	-2.0	0.06	ns
May	-	0.3	0.76	ns
June	-	0.8	0.44	ns
July	-	-1.7	0.10	ns
August	-	-0.9	0.38	ns
September	+	0.2	0.81	ns
October	+	0.9	0.35	ns
November	-	-2.3	0.03	*
December	-	-6.5	< 0.001	*

The results of the periphyton (Aufwuchs) collection in the Niobrara River are reported in Table 3-5 and can be used as a baseline for future measurements. Qualitative periphyton samples were obtained from woody stem at Site 3 and the epipsammon (sand surface) at Site 1, during July 1988. The species and relative abundance are presented in Table 3-6. The algae on the Site 3, woody stems made up a "crusty" type of growth. Within a mucilaginous algal matrix was a large amount of minute sand grains. The soft algae was primarily green algae (Chlorophyta), dominated by Chaetophora and Calothrix. Diatoms associated were mostly small, epiphytic, or attached in growth form. The epipsammon sample from Site 1 was greenish in appearance and dominated by blue-green algae (Cyanobacteria), primarily Anabaena. Sponge spicules were observed in the samples. Additionally, adults of the sponge parasite, Sisyra vicaria (Walker) (Neuroptera: Sisyridae) was collected by light trap at Site 1. The diatoms, in contrast to the Site 3 woody stem community, were larger in size, with a number of keeled and unattached forms.

3.3.2 Homestead National Monument

Water chemistry values are presented in Table 3-7. Like many other prairie region streams, high nitrogen and phosphorus concentrations indicate effects of agriculture. Kjeldahl nitrogen and NH_4-N values were highest in spring. Natural concentrations of total phosphorus in natural waters is usually less than 0.01 mg/l (Meybeck 1982, Hem 1985). Phosphorus in Cub Creek averaged 0.59 g/l at Site 1 and 0.56 g/l at Site 2. The highest concentration

Table 3-5. Values of periphyton samples, Agate Fossil Beds National Monument, Nebraska, reported as dry weight (Dry Wgt.) and ash-free dry weight (AFDW) in grams.

	Site 1		Site 2		Site 3	
Date	Dry Wgt.	AFDW	Dry Wgt.	AFDW	Dry Wgt.	AFDW
14-VII-88	931.1	135.9	1342.2	75.0	1213.9	132.1
14-VII-88	674.8	121.1	159.0	15.1	481.2	69.8
14-VII-88	--	--	560.0	54.3	1016.9	779.0
14-VII-88	--	--	913.4	78.3	390.8	41.9
14-VII-88	--	--	399.0	42.0	511.3	76.3
11-VIII-88	1719.5	1633.2	315.3	282.3	1049.3	963.6
11-VIII-88	4193.7	4026.8	319.8	288.9	1197.9	1069.2
11-VIII-88	4328.0	4150.1	1522.1	1445.8	1071.0	909.9
11-VIII-88	7519.2	7300.8	1514.0	1394.0	105.3	79.4
11-VIII-88	8814.4	8608.1	--	--	1009.7	897.4
16-IX-88	2092.5	1991.5	378.2	353.6	488.1	439.7
16-IX-88	1475.2	1364.0	362.4	311.0	16571.0	1574.0
16-IX-88	3296.6	3180.8	642.1	588.0	506.1	379.0
16-IX-88	1135.0	1058.1	906.9	848.3	1282.3	1207.0
16-IX-88	1560.9	1469.0	441.0	401.0	--	--
16-X-88	1568.8	1492.5	2798.4	2726.8	723.2	669.6
16-X-88	1332.5	1279.6	645.2	623.0	621.2	562.4
16-X-88	711.6	677.2	1842.5	1792.0	801.8	737.2
16-X-88	1298.7	1470.5	3493.1	3405.3	1547.5	1462.0
16-X-88	765.7	739.5	3796.4	3704.2	1395.6	1303.5

Table 3-6. Periphyton identified and relative abundance estimates from Agate Fossil Beds National Monument, July 1988. rare = 1, common = 4.

Woody Stem, Site 3	
Chaetophora spp.	4
Calothrix (*breviarticulata*)?	4
Calothrix (*fusca*)?	3
Chaetonema sp.	3
Stigeoclonium spp.	3
Scytonema (*crispum*)?	2
Oedogonium sp.	2
Draparnaldia sp.	1
Oscillatoria sp.	1
Scenedesmus sp.	1
Plectonema sp.	1
Epipsammon sample, Site 1	
Anabaena sp.	4
Oscillatoria sp.	3
Spirulina sp.	1
Merismopedia sp.	1
Scenedesmus sp.	1
Pediastrum sp.	1
Closterium sp.	1

Table 3-7. Water chemistry values, Cub Creek, Homestead National Monument, Nebraska: Total kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_4-N), total phosphorus (Total P), total organic carbon (TOC), alkalinity (Alk.), water temperature (Temp), and pH.

Site 1

Season	TKN (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	Total P (mg/l)	TOC (mg/l)	Alk. (µeq/l)	Temp (°C)	pH
Summer	1.53	1.50	0.34	0.98	22.3	8674	22.0	7.6
Autumn	2.35	1.16	0.06	0.77	28.7	3541	12.0	7.5
Winter	0.99	0.90	0.61	0.11	4.9	17378	0.5	7.5
Spring	3.54	0.50	1.10	0.52	17.7	5715	11.0	7.8
Mean	2.10	1.02	0.53	0.59	18.4	8827	11.4	7.6

Site 2

Season	TKN (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	Total P (mg/l)	TOC (mg/l)	Alk. (µeq/l)	Temp (°C)	pH
Summer	0.86	0.19	0.00	0.81	23.4	8785	22.5	7.9
Autumn	0.98	1.53	0.00	0.81	105.0	3310	13.0	7.8
Winter	1.03	1.03	0.52	0.19	9.0	16981	0.5	7.5
Spring	3.90	0.60	1.50	0.41	10.1	1716	11.0	7.8
Mean	1.69	0.84	0.51	0.56	36.9	7698	11.8	7.8

was 0.98 g/l in summer at Site 1 and the lowest values were in winter.

3.3.3 Pipestone National Monument

Water quality of Pipestone Creek has been a concern at least since 1982 when a large fish kill occurred. Agricultural chemicals and fertilizers were believed to be the cause of the kill. Two other pollution incidents of note have been recorded recently and the Minnesota Pollution Control Agency implicated small industrial and urban sources from Pipestone. Copies of the Investigator's Annual Reports submitted to the National Park Service, 1984-1988, are included in Appendix B. Four pesticides were found to occur in Pipestone Creek in **PIPE** in late summer 1985, and additional seven were found in low concentrations in a follow-up sample in late autumn 1988 (Appendix B).

Water chemistry values are presented in Table 3-8. Periodic higher nitrogen and phosphorus concentrations indicate continued effects of agriculture. Total phosphorus in Pipestone Creek averaged 0.12 g/l at Site 1 and 0.16 g/l at Site 2. The highest concentrations were in the summer averaging about 0.30 g/l. Phosphorus levels exceeded the U.S. Council on Environmental Quality (CEQ 1975) maximum "benchmark" level of 0.03 mg/l on every sampling date. Nitrate-nitrogen levels were highest in autumn and winter. On every date nitrate-nitrogen levels exceeded the U.S. Council on Environmental Quality (CEQ 1975) standard for protection of aquatic life, in winter the nitrate-nitrogen levels at

Table 3-8. Water chemistry values, Pipestone, Pipestone National Monument, Minnesota: Total kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_4-N), total phosphorus (Total P), total organic carbon (TOC), alkalinity (Alk.), pH and water temperature (Temp).

Site 1

Season	TKN (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	Total P (mg/l)	TOC (mg/l)	Alk. (μeq/l)	pH	Temp (°C)
Summer	1.71	2.72	0.04	0.27	15.3	7045	7.9	16.5
Autumn	0.50	5.07	0.00	0.06	7.4	15264	8.2	12.0
Winter	0.70	10.53	0.00	0.09	9.0	7082	7.4	2.0
Spring	0.60	1.80	0.00	0.05	8.5	4212	8.0	7.0
Mean	0.88	5.03	0.01	0.12	10.1	8401	7.9	9.4

Site 2

Season	TKN (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	Total P (mg/l)	TOC (mg/l)	Alk. (μeq/l)	pH	Temp (°C)
Summer	1.40	1.41	0.11	0.32	14.0	6829	7.8	19.2
Autumn	0.50	5.95	0.11	0.06	20.8	15839	8.0	12.0
Spring	0.40	2.10	0.30	0.10	8.2	4533	8.0	10.5
Mean	0.77	3.15	0.17	0.16	14.3	9067	7.9	13.9

Site 1 (there was no sample taken at Site 2) exceeded the U.S. EPA (1976) drinking water criterion.

3.3.4 Herbert Hoover National Historic Site

Like other typical streams transversing historic agricultural lands (Menzel et al. 1984), West Branch Wapsinonoc Creek has elevated nutrient and turbidity levels. Water chemistry results are presented in Table 3-9. Nitrate levels were especially high. In autumn and spring levels exceeded the widely used U.S. Environmental Protection Agency (1976) water quality criterion for drinking water of 10 mg/l NO_3-N). Nitrate levels were also high in summer. Kjeldahl nitrogen was highest in summer. Total phosphorus levels were also highest in summer and autumn, with measures of 0.15 and 0.31 mg/l. Turbidity was not measured, but **HEHO** personnel have observed periods of high turbidity, probably due to runoff during rainfall. The water of the creek is slightly alkaline with pH averaging 7.8 for the sampling season. The water chemistry of West Branch Wapsononoc Creek appears similar to other small to medium size agricultural region streams (Menzel et al. 1984).

3.3.5 George Washington Carver National Monument

Significant ground and surface water contamination has been documented in the **GWCA**. Aley and Aley (1985) investigated the hydrology and sources of contaminants of the springs within the bordered of **GWCA**. They found many springs were contaminated with domestic sewage wastes. The major source of the sewage was the West Diamond Sewage Lagoon. They reported ongoing cooperative efforts between the National Park Service and the city of

Table 3-9. Water chemistry values, Herbert Hoover National Historic Site, Iowa: Total kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_4-N), total phosphorus (Total P), total organic carbon (TOC), alkalinity (Alk), pH and water temperature (Temp).

Season	TKN (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	Total P (mg/l)	TOC (mg/l)	Alk. (μeq/l)	pH	Temp (°C)
Summer	1.00	8.95	0.00	0.15	12.7	6943	7.5	17
Autumn	0.16	14.28	0.07	0.31	3.7	4271	8.0	8
Spring	0.20	24.90	0.20	0.02	3.4	3423	8.0	4
Mean	0.45	16.04	0.09	0.16	6.6	4879	7.8	10

Diamond to improve the water quality. Further, they identified sites potentially hazardous to spring water quality, including: agricultural, sewage, dump and salvage yard, industrial, transportation routes, petroleum storage, and chemical storage. A significant concern as a source of mercury contamination of water and sediment are sites of a former seed treating operation in Diamond. Non-point source groundwater contamination was also addressed in the study.

In her study of water quality of **GWCA**, Boyt (1986) measured flow, temperature, pH, turbidity, dissolved oxygen, alkalinity, specific conductance, fecal coliform, fecal streptococcus, BOD, total kjeldahl nitrogen, nitrates, nitrites, ammonia, and total phosphorus. Boyt found high fecal bacteria levels from both human and animal sources in both Carver and Harkins Branch. She found that during high flows both streams are significantly more degraded. Additionally, Harkins Branch, which flows above the Park adjacent to a dairy operation, was significantly more degraded than Carver Branch.

Water chemistry results are presented in Table 3-9. The pH of the creeks through **GWCA** was circumneutral. Phosphorus and nitrate at the three study sites indicate some organic enrichment. Over the year the mean total phosphorus levels at Harkins and Carver was 0.08 mg/l, and was 0.01 mg/l at Williams. The highest value at Carver was obtained in winter, while Harkins had its highest values in summer and autumn. Nitrate-nitrogen concentrations equalled or exceeded 1.9 mg/l at all three sites autumn through spring. Lowest

nitrate levels were found in summer. TOC concentrations in autumn on Carver and Williams both exceeded 90 mg/l. Allochthonous leaf input may account for these values. Photosynthetic activity could contribute to the next highest TOC concentrations in summer.

3.3.6 Wilson's Creek National Battlefield

Elevated nutrient levels are present in Wilson Creek and Skeggs Branch. Water chemistry results are presented in Table 3-11. Total phosphorus averages were high at both Wilson Creek sites throughout the study. Levels of phosphorus in Skeggs Branch were low during the sampling period except for 27 June 1990 when total phosphorus was elevated, but not reaching the levels of the Wilson Creek sites. Nitrate-nitrogen levels were also high throughout the sampling period at all three sites, although levels were consistently higher in Wilsons Creek as compared to Skeggs Branch. Wastewater and farm runoff are known as major sources of phosphorus and nitrogen.

Table 3-10. Water chemistry values obtained for each site, on each sampling date and means for sampling period, George Washington Carver National Monument, Diamond, Missouri.

Carver

Sample	Tot. P mg/l	NO3-N mg/l	TKN mg/l	NH4-N mg/l	TOC mg/l	Alk µeq/l	pH	temp °C
Summer	0.06	0.72	0.00	0.00	9.2	756	7.2	17
Autumn	0.09	1.94	0.30	0.03	118.0	4116	--	--
Winter	0.19	2.33	0.29	0.08	2.0	7207	7.2	6
Spring	0.00	2.50	0.20	0.10	2.7	1504	7.2	10
Mean	0.08	1.87	0.20	0.05	33.0	3396		

Williams

Sample	Tot. P mg/l	NO3-N mg/l	TKN mg/l	NH4-N mg/l	TOC mg/l	Alk µeq/l	pH	temp °C
Summer	0.02	0.58	0.30	0.12	19.9	864	7.5	21.5
Autumn	0.03	2.33	0.33	0.09	93.5	3297	--	--
Winter	0.00	2.73	0.00	0.00	2.0	2250	7.8	5
Spring	0.00	1.90	0.20	0.20	2.7	1278	6.8	12
Mean	0.01	1.89	0.21	0.10	30	1922		

Harkins

Sample	Tot. P mg/l	NO3-N mg/l	TKN mg/l	NH4-N mg/l	TOC mg/l	Alk µeq/l	pH	temp °C
Summer	0.13	0.73	0.66	0.02	17.7	755	7.2	--
Autumn	0.14	2.60	0.26	0.03	11.5	3834	--	--
Winter	0.05	2.07	0.65	0.46	3.0	6713	7.2	2
Spring	0.00	2.80	0.30	0.10	3.4	1131	6.8	9
Mean	0.08	2.05	0.47	0.15	9.0	3108		

Table 3-11. Water chemistry values, 1988-1990, Wilson's Creek National Battlefield, Missouri: Total kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_4-N), total phosphorus (Total P), total organic carbon (TOC), alkalinity (Alk), pH and water temperature (Temp).

Wilson Upper

Season	TKN (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	Total P (mg/l)	TOC (mg/l)	Alk. (μeq/l)	pH	Temp (°C)
26Jun89	0.00	0.78	0.00	0.35	--	580	7.3	21
15Aug89	0.88	7.40	0.00	1.98	8.1	3677	7.5	22
25Oct89	0.56	7.66	0.13	0.90	7.3	10253	--	--
07Apr90	4.20	3.10	0.30	0.93	4.2	3897	--	--
27Jun90	2.00	4.50	0.50	2.40	16.0	1777	--	--
Mean	1.53	4.69	0.19	1.31	7.1	4037	7.4	22

Wilson Lower

Season	TKN (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	Total P (mg/l)	TOC (mg/l)	Alk. (μeq/l)	pH	Temp (°C)
26Jun89	0.23	1.60	0.21	1.36	--	1470	7.7	22
15Aug89	1.12	6.20	0.00	1.69	156.0	3670	7.8	24
25Oct89	0.80	7.20	0.00	0.47	6.7	10175	--	--
07Apr90	4.60	2.90	0.00	1.24	4.6	3796	--	--
27Jun90	2.10	5.10	0.20	2.62	10.1	1787	--	--
Mean	1.77	4.60	0.08	1.48	35.5	4180	7.8	23

Skeggs

Season	TKN (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	Total P (mg/l)	TOC (mg/l)	Alk. (μeq/l)	pH	Temp (°C)
26Jun89	0.11	0.66	0.10	0.01	14.4	3165	7.9	19
15Aug89	0.23	7.20	0.00	0.03	143.0	20	7.8	18
25Oct89	0.01	2.67	0.00	0.02	2.4	12200	--	--
07Apr90	2.20	2.30	0.00	0.00	2.2	3520	--	--
27Jun90	0.30	2.30	0.20	0.15	36.0	1902	--	--
Mean	0.57	3.03	0.06	0.04	39.6	4161	7.9	19

4.0 BENTHIC MACROINVERTEBRATES

4.1 *Methods*

4.1.1 Quantitative Sampling

Sampling methods available for characterizing benthic macroinvertebrate communities vary in their effectiveness. These sampling methods usually can be classified as being quantitative, semiquantitative, or qualitative. Quantitative sampling, used to obtain numerical data to estimate the absolute abundance of each species per unit area, is usually habitat specific (Platts et al. 1983). This methodology provides data on population densities that may be used to detect variations in time and space. These types of techniques are often time consuming and expensive. Semiquantitative and qualitative designs yield data on species richness and relative abundance (Merritt et al. 1984, Lenat 1988). In addition to choosing a sampling device, the appropriate sampling design used, including type of equipment, sampling frequency, number of samples and sampling habitats, needs to be carefully determined by considering the objectives of the study (Merritt et al. 1984, Platts et al. 1983).

The quantitative Surber square-foot bottom sampler (**PIPE**, **HEHO**, **GWCA**, **WICR**) (Fig. 4-1), modified Hess bottom sampler (**AGFO**) (Merritt et al. 1984b, Fig. 4-2) and the semiquantitative Hester-Dendy multiple plate sampler (**AGFO**, **HOME**) (Flannagan and Rosenberg 1982, Fig. 4-3) were used during the course of this study. All three are commonly used to sample shallow streams and rivers. At every park unit five replicate samples were taken at each site and

on each date.

Bottom samplers, such as the Surber or the Hess sampler, are direct sampling methods. All organisms within the area of the sampler on the natural stream bottom are collected. Bottom samplers are often employed to sample shallow rocky riffles rather than other stream areas (i.e. pools) because riffles generally have higher biotic diversity and greater accessibility (Platts et al. 1983).

Artificial substrate samplers, such as the Hester-Dendy multiple plate sampler, are intended to provide standardized substrates that are comparable, when placed in different habitats within the aquatic environment (Beak et al. 1973). They rely on invertebrates colonizing the sampler within a determined amount of time, after which the sampler is retrieved and the invertebrates collected. These substrates are recommended because they can reduce variation among samples and are easier to use (Rosenberg and Resh 1982). The Hester-Dendy multiple plate sampler simulates woody retention structure habitats (debris dams) that occur naturally in many Great Plains streams. This habitat is most often found in areas of woody riparian vegetation, which is a source of wood and leaf litter. A review and critique of the use of artificial substrates in studying freshwater benthic macroinvertebrate communities may be found in Rosenberg and Resh (1982).

Any type of sampler is designed specifically to be used for sampling one or more aquatic habitats (e.g. riffles, pools, vegetation). The species and relative abundance of organisms

collected using different methods are expected to vary. For example, the Hester-Dendy sampler would not be expected to efficiently sample the burrowing mayfly *Hexagenia limbata* Serville, which burrows into the stream bottom. Rather, the Hester-Dendy sampler would favor organisms that attach or cling to exposed solid substrates in the flowing water column, such as black flies, *Simulium* spp. and baetid and heptageniid mayflies. The results obtained using different samplers also reflect the natural spatial (within stream) and temporal (diel and seasonal) variability of benthic macroinvertebrate communities. This natural variability combines with variability due to collection procedure, which investigators should endeavor to minimize. Collection procedures include time of sampling, sampling frequency, number and type of habitats sampled, placement of the sampler, number of replicates, processing method, taxonomic resolution, and efficiency of different operators.

The Surber sampler was used to sample four park units, **PIPE**, **HEHO**, **GWCA**, **WICR**. This sampler consists of a capture net and frame, which supports the net and defines the sampling area. The sampling area of the samplers was 0.0929 m^2 (1 square foot). At **PIPE**, **HEHO**, and **GWCA**, the mesh of the nylon capture net had 1.050 mm openings and at **WICR** the mesh openings were 0.20 mm (Wildco, Wildlife Supply Company, Saginaw, Michigan). The sampler was placed on the stream bottom in areas where depth and current were sufficient to wash dislodged organisms into the capture net. The substrate within the sampler frame was disturbed with a garden

cultivator to a depth of 8-10 cm in order to dislodge organisms. Individual rocks were brushed with a vegetable brush and then visually inspected in order to free any clinging organisms. The catch net was washed several times to concentrate the contents into the end. Contents were placed into a labeled plastic bag by inverting the net, and preserved by adding formaldehyde to a concentration of approximately 5%. Macroinvertebrates were enumerated and identified to the lowest practical taxonomic level (Table 4-1). Final storage of samples was in 80% ethanol. The Hess bottom sampler was used the first year at **AGFO**. Its use is similar to that of a Surber sampler. The bottom diameter of the sampler used was 0.330 m (area = 0.0855 m^2) and the mesh size of the catch net was 202 μm (Wildco, Wildlife Supply Company, Saginaw, Michigan).

Hester-Dendy multiple plate samplers were used to sample at **AGFO** (2nd year), and at **HOME**. Each Hester-Dendy sampler (Fig. 4-3) consisted of nine 7.6 cm x 7.6 cm hardboard plates, connected by a long eye bolt. The plates were separated by 3-mm spacers and in total provided 0.0929 m^2 of surface area for colonization. Five samplers at each site were suspended by nylon cord between the water surface and substrate. After a 30 - 35 day colonization period the samplers were carefully pulled from the water and placed immediately into a labeled plastic bag. A small amount of stream water was added, then enough formaldehyde to achieve a 5% solution. Macroinvertebrates were enumerated, identified to the lowest practical level (Table 4-1), and placed in 80% ethanol for storage.

4.1.2 Data Analysis

For data analysis a "sample" was defined as the mean number of organisms of each taxon found in the five replicate samples at each site and date. Data from the macroinvertebrate sampler were analyzed to obtain basic benthic aquatic community data including taxa richness and density of macroinvertebrates. Sites and time periods are compared, and pertinent life history information is provided.

The number of qualitative EPT (Ephemeroptera/Plecoptera/Trichoptera) taxa was the number of taxa, in the three orders, represented in a sample. Many species in these three orders are considered pollution-sensitive (Hawkes 1979). Surveying the number of EPT taxa over time and comparing the number with streams with those of similar size and in close proximity may be indicative of present and past water quality.

The measurement of diversity has two components: taxa richness and relative abundance. Richness is simply a count of the number of taxa (i.e. species) being present. Relative abundance, or evenness, is a description of how the organisms in a community are distributed among the taxa. In this study we are using three measures of diversity to describe the stream communities: taxa richness, Shannon (or Shannon-Wiener) diversity index, and Simpson's index. One of the simplest and most basic measures used in aquatic ecology is taxa richness, which is simply the number of different taxa found in a given space and time. The Shannon diversity index and Simpson's index utilize both of the components

of diversity and are based on the proportional abundance of species. A recent review of the use and meaning of ecological diversity may be found in Magurran (1988). Washington (1984) reviewed the ecological application of diversity indices along with biotic and similarity indices.

The Shannon diversity index is based on information theory and relates to the uncertainty of the identity of an individual chosen at random (Washington 1984, Magurran 1988). Shannon's index was calculated as:

$$H' = -\Sigma p_i \ln p_i$$

where p_i is the proportion of individuals in taxon i, or more specifically, $p_i = n_i/N$ where n_i is the number of individuals in the i^{th} taxon and N is the total number of individuals in the sample. The Shannon index is sometimes calculated with $\log_2$ or $\log_{10}$ rather than the natural log, and the values obtained would differ by a constant (Brower and Zar 1977, Magurran 1988). This index is one of the most widely reported in ecological literature (Washington 1984).

Simpson (1949) proposed a formula that gives the probability that two individuals drawn at random from a finite community will belong to different taxa (Washington 1984, Magurran 1988). Simpson's Index was calculated as:

$$D = (\Sigma n_i(n_i - 1)) / N(N - 1)$$

where n_i is the number of individuals in the i^{th} taxon and N is the total number of individuals in the sample. The value of Simpson's index ranges from 0 to 1 and decreases with increasing diversity.

Simpson's complement (1 - D) is presented in this report, since this modification makes higher values represent higher diversity. Simpson's Index is most sensitive to the abundant species, and less weighted toward sample size or species richness (Magurran 1988).

For data obtained at **WICR** the use of two biotic indices was explored: Hilsenhoff's family-level biotic index (Hilsenhoff 1988), and a biotic index developed for the southwest Missouri Ozarks (Youngsteadt and Witherspoon Undated). These results are presented in Appendix D.

Population dynamics or life-table parameters of key species have been suggested as signs to monitor for indication of ecosystem change (Schindler 1987, Davis et al. 1988). Species that indicate ecosystem changes have the following attributes: sensitive to environmental perturbations, short-lived, and low powers of dispersal (Schindler 1987). Presented below are sampling results of and ecological information about common taxa occurring in each park unit.

Research in aquatic ecology has stressed the importance of examining the benthic community from both a functional and a taxonomic standpoint. The functional aspect is important because it is indicative of ecological processes, including organic matter processing. In this study community function was examined indirectly by classifying the macroinvertebrates into functional feeding groups based on their primary mode of feeding listed in Merritt and Cummins (1984).

Six functional feeding groups (Table 4-2) were distinguished

in this study. Organisms that consume fine particulate organic matter (FPOM, < 1 mm) are classified as collectors. These collectors are further separated into gatherers, those that obtain detritus that has been deposited on the substrate, and filterers, those that utilize specialized structures to obtain FPOM from the water column. Scrapers are herbivores; they shear attached algae and associated material from solid submerged substrates. Shredders chew coarse particulate organic matter (CPOM > 1 mm), usually terrestrial leaf litter and associated microbes. Predators consume living animal tissue. The 'other' category includes pupae, which do not feed, and macrophyte piercers, which feed on fluids of living plants.

4.1.3 Qualitative Sampling

Qualitative benthic samples were taken with a standard D-frame kick net. The major objective was to obtain specimens from the many microhabitats of both streams that were not sampled with the quantitative device. Selected specimens were returned alive to the laboratory for rearing to adult stage for positive identification. Additionally, emergent adult insects were obtained with an aerial net by sweeping riparian vegetation or capturing flying insects, and attracting insects with a black light trap. Others were collected by carefully examining exposed debris and rocks. A voucher collection of selected species listed in Appendix A has been deposited in the Colorado State University Insect Collection, Fort Collins.

4.2 *Other Prairie Streams*

Matthews (1988) reviewed much of the ecological work performed in North American prairie streams. Menzel et al. (1984) described ecological alterations to some prairie-agricultural streams in eastern Iowa. Work has been performed in the southern prairie region, including Texas (Davis 1980, Henry 1986) and Oklahoma (Morris and Madden 1978). Many ecological studies have been performed in King's Creek, a tallgrass prairie creek in the Konza Prairie Research Natural Area, Kansas. Research has included work on leaf litter processing (Smith 1986, Tate and Gurtz 1986), organic matter loading and processing (Gurtz et al. 1982, McArthur et al. 1985b), aquatic insect emergence (Gray 1989), and water quality (McArthur et al. 1985a). In the northern prairie, McCoy and Hales (1974) surveyed the biota and physical and chemical characteristics of eight streams in eastern South Dakota. In his treatise on the Turtle River in eastern North Dakota, Neel (1985), documented annual and seasonal changes of the physical, chemical, and biotic features of this northern prairie stream.

4.3 *Agate Fossil Beds National Monument*

A Hess sampler (Fig. 4-2) was used to quantitatively sample the benthic macroinvertebrate community beginning June 1988. Each of three sites was sampled every two weeks in June, July and August, and monthly in September and October. Five replicate samples were taken at each site on each date. Sampling dates are presented in Table 4-3. An ice cover of 30 to 45 cm prevented sampling with the Hess sampler from November to March except for 18

individuals/m^2 of bottom substrate for Sites 1, 2, and 3 respectively (Table 4-6). Site 2 had consistently lower density estimates than the other two sites (Fig. 4-6). Sites 1 and 2 on 30 June and 28 July had lower estimates than the rest of the year. Site 1 on 16 June was much higher than on other dates. The winter Site 1 sample had lower density than most of the year.

The Ephemeroptera and Diptera were the two most abundant groups in terms of mean abundance for each site (Table 4-7). In the mean of the Hess samples these two groups accounted for between 73% and 75% of the individuals (Table 4-8). The Oligochaeta were the next most abundant group, comprising for between 10% and 13% of the individuals. Table 4-9 presents mean densities for each taxon.

Both diversity indices, Shannon's H' and Simpson's complement, indicated similar trends (Fig. 4-7). From the spring through the fall, at all three sites the Shannon diversity was usually between 2.0 and 2.5, and Simpson's complement usually was between 0.8 and 0.9. There were conspicuously low diversity numbers, however, for the 30 June 1988 sample at Sites 1 and 2 and the 28 July 1988 sample at Site 1. The winter sample had lower diversity (Shannon 1.72, Simpson 0.67) than the remainder of the year.

4.3.2 Hester-Dendy Results

In the Hester-Dendy samples 39 taxa were identified; at site 1 there were 34 and site 3 there were 33 (Table 4-4). Eleven of these taxa were not collected in the Hess sampler, and 16 taxa collected in the Hess sampler were not identified from Hester-Dendy samples. Fourteen of the taxa were in EPT orders, twelve at each

site (Table 4-5). The number of EPT taxa in relation to the total taxa found on successive sampling dates appeared to be relatively constant (Fig. 4-8).

Hester-Dendy density estimates were 3655 and 4450 individuals/m^2 for sites 1 and 3, respectively (Table 4-6). The autumn samples were highest at each site and the winter Hester-Dendy density estimate at site 1 of 1173 individuals/m^2 was lower than other samples (Fig. 4-6). The Diptera were the most abundant group, constituting 54% and 83% of the individuals at site 1 and 2 respectively, and the Ephemeroptera accounted for 24% and 11% of the individuals (Tables 4-7, 4-8). At site 1 the Oligochaeta were the next most abundant group with almost 13% of the organisms. The mean densities for each taxon are presented in Table 4-9.

As with the Hess sampling results, both diversity indices performed similarly to each other (Fig. 4-9). Highest diversity values were found in the summer and the lowest in the winter and spring. Winter and spring samples were dominated by Orthocladiinae midges. The autumn diversity values indicated a substantial difference between sites 1 and 3. Higher numbers of Simuliidae larvae at site 3 during autumn accounted for these lower diversity values.

4.3.3 Ephemeroptera (Mayflies)

The Ephemeroptera were either the most or second most abundant group in the yearly mean for the benthic samples at each site (Tables 4-7, 4-8). The individuals in the benthic samples belonged to a number of different genera with a variety of life histories.

The relative abundance of mayfly species in benthic sampling is presented in Table 4-10. Nine species were identified from the adults and larvae.

Three baetid species were commonly found in the Monument, Baetis dardanus McDunnough, Acentrella insignificans (McDunnough), and Fallceon quilleri (Dodds) (Appendix A.1). Individuals were only identified to family in the quantitative sampling. Until recently (Waltz and McCafferty 1987a, 1987b) these three species were classified in the genus Baetis. McCafferty and Waltz (1990) made numerous systematic changes in the family Baetidae. Maximum abundance of Baetidae was 615 individuals/m^2 at Site 1 on 16 June 1988. Baetis was also abundant during August and September in the Hess samples and was most abundant in the summer Hester-Dendy samples (Fig. 4-10). Baetis dardanus was apparently the most common Baetis species occurring at the **AGFO**. Baetis dardanus is widely distributed across central and western North America (Soluk 1981). This species is apparently univoltine in the Niobrara, and larvae prefer woody substrate or submerged aquatic plants. Carnevalo (1981) did not report this species from the Niobrara River. This may be due to the taxonomic literature available. Carnevalo (1981) does not cite three major references, Morihara and McCafferty (1979a, 1979b) and Soluk (1981) which clarified the taxonomy of this species and other species identified in his thesis.

Leptophlebia nebulosa (Walker) is widely distributed through much of North America (Edmunds et al. 1976). Larvae can be

collected from ponds and on the edges of medium sized streams. Leptophlebia nebulosa has a univoltine life cycle in the Niobrara River (Fig. 4-11). Leptophlebia development and emergence are dependent on water temperature. In benthic stream samples the larvae were collected in greatest numbers in late summer and fall (Fig. 4-11), and except for site 3 during the Hess sampling, larvae made up over 20% of the mayflies collected (Table 4-10). After ice break the majority of the larvae migrate into the overflow areas of the flood plain of the river; however, some of the larvae remain in the river. Clifford et al. (1979) suggested that this migration is a mechanism to escape from spring turbulence in the main channel. Leptophlebia larvae are classified as fine particle detritivores. Clifford et al. (1979) reported 96% of the diet of L. cupida (Say), a very closely related species, as detritus. They stated that this percentage actually represented the relative amounts of food particles in the stream, and was not selective feeding by the larvae.

Larvae of Heptagenia diabasa Burks, a large heptageniid mayfly, were most common in the **AGFO** in the late spring and early summer. At site 1 during the Hess sampling, this species averaged $270/m^2$, and the maximum density was $2006/m^2$ on 16 June 1988 at Site 1 (Fig. 4-12). These active larvae are dorso-ventrally flattened and generally occur on firm surfaces and in debris in flowing water. This species is distributed throughout the central U.S. and Canada (Edmunds et al. 1976), and is univoltine. Heptagenia diabasa has been previously reported to be abundant throughout the

Niobrara River system (Carnevalo 1981).

Larvae of the burrowing mayfly, Hexagenia limbata Serville, are easily recognized by the fringed gills that wave above the abdomen and curving mandibular tusks. In streams and lakes larvae dig a U-shaped burrow where, by action of their gills, where they create a flow of water which carries food and oxygen. Hexagenia limbata is widely distributed throughout North America and can occur in extremely large numbers. They are usually found where the substrate is soft enough for burrowing, yet dense enough to support the burrow, and have been reported to tolerate low oxygen conditions, even below 1 ppm (Edmunds et al. 1976). At Site 2, this species was found at an average density of $214/m^2$, and in the 25 August 1988 sample occurred at $596/m^2$ (Fig. 4-13). It appears that Hexagenia limbata has a two year life cycle in the upper Niobrara. Adults can be commonly seen hanging on streamside vegetation throughout the summer.

4.3.4 Odonata (Dragonflies and Damselflies)

Twenty-three species of Odonata in seven families were identified from adults collected in the **AGFO** this study (Appendix A.1). Most were collected only in qualitative collections. **AGFO** visitors can observe the colorful adults flying along the river and adjacent wet areas throughout the summer months. Both of the sampling methods utilized probably underestimate the number of Odonata in the stream. Larvae prefer areas such as undercut banks and deeper pools.

Larvae in the family Calopterygidae were the most common

Odonata in the benthic samples, and larvae and adults were commonly observed during qualitative sampling. The species found were Calopteryx maculata (Beauvois), Calopteryx aequabilis Say, Hetaerina americana (F.).

The common black-winged damselfly, Calopteryx maculata, begins emerging in early June. Adults live for about two weeks and become rare or absent by September. Territorial behavior by males is well-documented (Johnson 1962). Eggs are deposited by females in almost any kind of plant tissue throughout late June and July, and begin to hatch in 26-29 days (Martin 1939). The development period for the 11-12 instars is about a year. Larvae are general carnivores, feeding on other invertebrates.

The other species of Calopteryx, occurring in the upper Niobrara is Calopteryx aequabilis, and appears to be more abundant than C. maculata. As Martin (1939) reported, the life cycle of C. aequabilis is 2 years. In the Niobrara River, eggs are deposited into plant material during June and July and eggs hatch in about three weeks. Larvae spend two years feeding on other invertebrates. Emergence is generally in late May into June.

Adults of the Ruby-spot, Hetaerina americana, have longer flight periods, often until the first heavy frost in September. This species is not abundant in the **AGFO**. It appears this species is univoltine at the study sites in the **AGFO**.

4.3.5 Plecoptera (Stoneflies)

Plecoptera is an order most often associated with cold mountain streams. Great Plains streams generally support only

tolerant species, which often are geographically widespread. Four species of Plecoptera were identified from the **AGFO** during this study.

Taeniopteryx burksi Ricker and Ross is widely distributed east of the Rocky Mountains (Ricker and Ross 1968, Kondratieff and Ward 1987). Larvae are usually found in slow moving water associated with leaf litter or organic debris. Taeniopteryx is one of the "large winter stoneflies," so called because adults are active from January to March. Eggs hatch from April to May. Larvae apparently diapause deep in the substratum as 4th or 5th instar. Diapause is broken in late September to October with rapid growth until emergence. In the benthic samples Taeniopteryx burksi larvae were collected in greatest abundance in the autumn months at Site 1. The greatest larval density was $394/m^2$ on the Hester-Dendy samplers at Site 1 on 21 October 1989. Mature larvae were observed in large numbers near Site 1 in February.

Two Isoperla species occurred in the Niobrara River in the **AGFO**, a widespread, primarily western North American species, Isoperla quinquepunctata Banks, and an eastern and central North American species, I. marlynia Needham. Most life histories of Nearctic Isoperla species indicate univoltinism (Stewart and Stark 1988). I. quinquepunctata was commonly collected from the Niobrara in the **AGFO**.

4.3.6 Trichoptera (Caddisflies)

Sixteen species of Trichoptera in six families were identified, many only from light trap collections. Trichoptera

species were not especially abundant in the benthic samples. Trichoptera ranged from < 1% to 3% of the individuals collected at each site during both years (Table 4-8).

Hydropsyche bronta Ross was the most common Trichoptera found at the **AGFO**. All Hydropsyche are filter-feeders in running water. They are capturing particles from the water column with a silk net. Hydropsyche bronta was originally described from Michigan and ranges from the Appalachians westward to Alberta and into southeastern Wyoming (Schefter and Wiggins 1986). This species is known to maintain large populations in streams disturbed by agriculture and runoff from roads and dilute treated sewage (MacKay 1984). Hydropsyche bronta prefers open shallow riffles of medium to larger streams where maximum summer temperatures exceed 24°C. This species has been reported to be trivoltine in southern Ontario (MacKay 1984, Rutherford and MacKay 1986). In the Niobrara River, H. bronta was commonly associated with woody debris, and from adult collections, the life cycle appears to be univoltine to bivoltine.

4.3.7 Diptera (True Flies)

Dipteran larvae may be found in almost any aquatic habitat and they are often numerous. Eight families were represented from the Niobrara River in the **AGFO**.

The family Chironomidae (midges) is an extremely large family with over 2000 species identified from the Nearctic Region and between 10,000 - 15,000 species worldwide (Coffman and Ferrington 1984). In freshwater ecosystems they are often the most abundant group of insects (Pinder 1986). Chironomidae were identified to

subfamily, and to tribes in the subfamily Chironominae, during the benthic sampling. The subfamilies Orthocladiinae and Tanytarsini were most commonly encountered in the Hess samples (Fig. 4-14). Hester-Dendy samplers favored the Orthocladiinae which had mean abundances of 1196 and 1824 individuals/m^2 at Sites 1 and 3 respectively (Fig. 4-15).

The orthoclads *Eukiefferiella* spp. and *Orthocladius* (*Orthocladius*) *obumbratus* Johannsen/*dorenus* (Roback) were the most common midges found in the benthic samples. Both these genera are difficult to separate from closely related groups.

Simulium vittatum Zetterstedt complex were the most common simuliid (black flies) in the Niobrara River in the **AGFO**. Pruess and Peterson (1987) reported that this species is found in almost every stream in Nebraska with appropriate habitat. They also reported it to be multivoltine with up to six generations. Larvae have a ring of hooked setae at the end of the abdomen for clinging to various substrates in flowing water. With both sampling techniques Simuliidae reached their peak abundance in autumn. Larval density on the Hester-Dendy samplers at Site 3 on 21 October 1989 was > 5000 individuals/m^2 (Fig. 4-16).

4.3.8 Oligochaeta (Aquatic Earthworms)

Oligochaeta, the aquatic segmented worms, is a class of the phylum Annelida. Individuals usually occupy the upper few cm of the substrate, and feed by ingesting the sediment. Many oligochaetes can thrive in extremely low oxygen conditions (Pennak 1989). Oligochaeta was the most abundant non-insect in the benthic

samples (Tables 4-7, 4-8). The greatest density of 1356 individuals/m^2 was reached on 16 June 1988 at Site 1 (Fig. 4-17).

4.3.9 Functional Analysis

The benthic macroinvertebrate community of the Niobrara River was clearly dominated by species considered to be collector-gatherers (Figs. 4-18, 4-19, Table 4-12). In the Hess samples collector-gatherers comprised 63%, 74%, and 78% of the individuals at Sites 1,2, and 3 respectively (Fig. 4-18, Table 4-12), and in the Hester-Dendy samples, 60% and 49% for Sites 1 and 3 respectively (Fig. 4-19, Table 4-12). Collector-gatherers were abundant throughout the year, especially during Hess sampling (Fig. 4-20). They reached their greatest relative abundance in the winter and spring during Hester-Dendy sampling (Fig. 4-21). The major collector-gatherers were Ephemeroptera (including *Baetis* spp., *H. limbata*, *L. nebulosa*, and *Caenis latipennis*), Oligochaeta, and Chironomidae (encompassing the subfamilies Orthocladiinae, and Chironominae). *Gammarus* sp. was also a collector-gatherer, abundant periodically at sites 1 and 2.

The collector-filterers were the second most abundant functional group represented. Collector-filterers obtain FPOM from the current. For the Hess sampling, collector-filterers comprised 18%, 13%, and 11% of the individuals at Sites 1,2, and 3 respectively (Fig. 4-17, Table 4-11), and 16% and 38% at Sites 1 and 3 for the Hester-Dendy sampling (Fig. 4-17, Table 4-11). The Tanytarsini midges and *Simulium* larvae were the most abundant collector-filterers over the course of this study. *Simulium* larvae

were most abundant in the autumn samples, and in the autumn 1989 samples at site 3, Simulium larvae, reached an abundance of 5080 individuals/m^2, accounting for 71% of the organisms in the sample (Figs. 4-15, 4-20). Tanytarsini abundances were more consistent throughout the year, but in the 28 July 1988 Hess sample at Site 1 reached an abundance of at 755 individuals/m^2 (Figs. 4-13, 4-19). Other collector-filterers included the trichopterans Hydropsyche and Cheumatopsyche, the ephemeropteran Isonychia, and the freshwater clam family Sphaeriidae.

Scrapers shear attached algae and associated material from solid submerged substrata. The ephemeropteran H. diabasa was numerically the most common scraper. The Gastropoda families, Ancylidae, Lymnaeidae, Physidae, and Planorbidae, were the other scrapers commonly encountered during the study. Heptagenia diabasa was especially abundant at Site 1 (Fig. 4-11), and scrapers accounted for 14% and 15% of the community in the first and second year. Scrapers made up about 6% of the fauna at the other sites during both years (Table 4-11).

Shredders are important in organic matter processing in many lotic systems because they help break down coarse particulate organic matter (CPOM > 1 mm), usually terrestrial leaf litter and associated microbes. Taeniopteryx burksi, Nectopsyche sp., Ptilostomis semifasciata (Say), Tipulidae, and Orconectes immunis (Hagen) were the shredders found in benthic collections. These taxa encompassed 2% or less of the individuals at each site during the first sampling year. Shredders made up 4% of the individuals

at Site 1 during Hester-Dendy sampling, and 0.1% at site 3 (Table 4-11). The especially low number of shredders at site 3 during the second year may be due to the multiple-plate sampler, poorly sampling the crayfish _Orconectes_. The Hess sampler also probably underestimated the _Orconectes_ population because crayfish prefer to reside in the undercut banks of the stream. _Orconectes_ probably plays an important role in processing large particulate organic matter in the stream. The winter stonefly _T. burksi_, another important shredder, reached its greatest abundance in the fall samples at site 1, correlated with the greatest leaf input. The Tipulidae were most abundant in the 18 February 1989 Hess sample, and at a density of 110 individuals/m^2 did account for 18% of the macroinvertebrate numbers.

Predators comprised between 1.5% and 3.8% of the fauna at all the sites (Figs. 4-17, 4-18, Table 4-11). Despite the fact that numerous predators were in the Niobrara River, none were collected especially abundantly by the quantitative methods. For example, relatively few Odonata larvae were identified despite adults often being abundant during sampling. The common habitat of many of these species are undercut banks and streamside debris, habitats not sampled by techniques employed.

4.3.10 Summary of Benthic Macroinvertebrate Data

The taxa identified from the **AGFO** during the course of this study are presented in Appendix A. The Niobrara River in the **AGFO** supports a fauna believed once typical of the western portion of the Great Plains, a mixture of midwestern, Rocky Mountain, and

widespread species. For example, the Ephemeroptera (mayflies) _Heptagenia diabasa_ Burks, and _Isonychia rufa_ McD., and the plecopteran (stonefly) _Taeniopteryx burksi_ Ricker and Ross are species common in streams in Illinois, Ohio, and Indiana, whereas the odonate (dragonfly) _Ophiogomphus severus_ Hagen is a Rocky Mountain species. The Trichoptera (caddisflies) _Cheumatopsyche pettiti_ Banks, and _Hydropsyche bronta_ Ross are widespread over the eastern half of North America.

Few studies of stream benthic macroinvertebrates have been conducted in the immediate region of the **AGFO**. Kondratieff and Ward (1987) found similar species composition in their brief survey of an eastern Colorado stream. Carnevalo (1981) specifically surveyed the mayflies of the Niobrara River. McCafferty discussed the biogeographic affinities of mayflies in the Black Hills region of South Dakota. Additionally, there is some unpublished work on the Pine Ridge area north of Harrison. Even though the Pine Ridge area is in close proximity to the **AGFO** it differs geomorphically and ecologically.

The predominance of the two collector groups indicates that the food base in the Niobrara River is FPOM. Although the stream bottom presumably receives large amounts of solar radiation, the sandy substrate of the river does not allow much surface colonization by algae. The lack of a major source of terrestrial leaf litter may be one reason to account for the low numbers of shredders in the river. The sand to sand/mud substrate typical of much of the river bottom, is not considered a good substrate for

many species, especially when compared to rocky-bottomed prairie streams. Certain species prefer the refuge of undercut banks, including calopterygid damselflies, Orconectes, and several beetle.

4.4 *Homestead National Monument*

Four seasonal samples at both sites were planned. Hester-Dendy samplers were collected in July 1989 (summer), October 1989 (autumn), January 1990 (winter), and April 1990 (spring). Five replicates were obtained on each date. The Site 1 spring sample was lost due to vandalism. Sampling dates are presented in Table 4-12.

4.4.1 Results

Cumulatively, 40 taxa were identified from Hester-Dendy samples. On individual sampling dates the number of taxa ranged from 5 to 26. At both sites, the most taxa were identified in summer, and the least in winter. Only four taxa were identified from the EPT orders in Hester-Dendy sampling (Fig. 4-22).

There was a wide range of density estimates from the Hester-Dendy samplers (Fig. 4-23). The two sites indicated similar trends. Densities were lowest in the winter samples. A density of over 19,000 individuals/m^2 was found in spring at Site 2, over four times higher than the next highest density (4300 individuals/m^2), found in summer at Site 1.

Both diversity indices, Shannon's H' and Simpson's complement, indicated similar trends. The diversity numbers calculated are considered low. The highest diversities were recorded in the

winter samples (Fig. 4-24).

Coleoptera and Diptera were the taxonomically richest groups found in quantitative and qualitative collections. Thirteen beetle taxa were identified from Cub Creek (Appendix A). The riffle beetle, Dubiraphia was the most common beetle colonizing the Hester-Dendy samplers (Table 4-13). Several of the beetle families commonly encountered in Cub Creek (e.g. Hydrophilidae, Haliplidae, Dytiscidae) are more common in slow moving depositional streams and lentic habitats.

Diptera and Oligochaeta were by far the most abundant groups in Cub Creek, together composing greater than 90% of all individuals collected at each site (Table 4-14, 4-15). Gastropoda and Nematoda are the only other groups that made up more than 10% of the individuals in single sample.

The great increase in density in spring comprised largely species of orthoclad midges (12,000 individuals/m^2, 65% of total) (Table 4-13). Cricotopus spp. and Eukiefferiella spp. appeared to be the most common genera. LeSage and Harrison (1980) provide life history information on 15 species of Cricotopus. They found all Cricotopus multivoltine, with five generations per year. Peak emergences were in late spring, which is consistent with our large number of larvae in early spring. A number of species in these orthoclad genera are considered tolerant of enriched, polluted, and turbid water.

Midges of the tribe Chironomini were most abundant in summer, autumn, and fall samples at both sites. Dicrotendipes spp. and

Polypedilum spp. were the dominant genera. Many common species in these genera are tolerant to various types of pollution, although a few species are found exclusively in unpolluted habitats (Simpson and Bode 1980).

Oligochaeta (see section 4.3.8) were the most abundant non-insects on the multiple plate samplers. This group reached its highest abundances in spring and summer (Table 4-13). Oligochaetes accounted for 27% of the individuals (5300 individuals/m^2) in the spring sample.

4.4.2 Functional Analysis

The collector-gatherers were conspicuously the most abundant functional feeding group found on the Hester-Dendy samplers (Fig. 4-25). For individual samples, abundance ranged from 73% to 98% of the individuals (Fig. 4-26). Orthacladiinae midges, Chironomini midges, and Oligochaeta were the dominant collector-gatherers.

Scrapers composed 7% of the individuals at site 1 and 23% at Site 2 in summer. The snails (Gastropoda) were the major scrapers in Cub Creek. Other scrapers include riffle beetles and the mayfly *Stenacron interpunctatum* (Say). In autumn, predators made up 11% and 14% of the individuals at sites 1 and 2 respectively. Larvae of the chironomid subfamily Tanypodinae were the most abundant predators. Other predators included odonates, *Sialis*, and several beetles. Shredders and collector-filterers never composed more than 1% of the individuals.

4.4.3 Summary of Benthic Macroinvertebrate Data

The macroinvertebrate species composition of Cub Creek reflects the physical nature of the stream. The creek is a low gradient stream with many extended pools, debris dams and beaver dam-building activity. Many of the species identified were more typical lentic forms. Members of the dominant taxa in the quantitative samples, Orthocladiinae, Chironomini, and Oligochaeta, are all commonly found in slow-flowing waters. The lotic species collected in quantitative samples may originate from the nearby Blue River and colonize Cub Creek when conditions are favorable. Those identified from qualitative sampling, such as adult Hydropsyche spp. (Appendix A.2), may also originate from the Blue River.

It is difficult to access how Cub Creek looked in the past. Comparisons with other streams in the prairie region are difficult. There are great ecological differences in streams in different parts of the region (Matthews 1988). For example, consistent flow and cobble substrates are typical of many northern prairie region streams, while southern streams generally have more irregular flow and fine particle substrates. Even within small areas, ecological conditions, turbidity for example, may vary greatly. It is also difficult to compare streams because few minimally impacted streams exist. Descriptions in pioneer journals may be the best evidence how prairie streams in this area appeared before the land was extensively cultivated (Menzel et al. 1984, Matthews 1988).

The most diverse benthic macroinvertebrate fauna are generally

found in riffle areas of streams. Lower species richness is associated with the sand and mud substrate, typical of Cub Creek. On the whole prairie streams today carry a higher sediment load than in pre-settlement time. Changes in hydrology and riparian vegetation have effected the physical habitat of prairie region streams and therefore, the types of organisms that exist in these streams.

4.5 *Pipestone National Monument*

A Surber square-foot bottom sampler (Fig. 4-1) was used to obtain seasonal samples at the two study sites on Pipestone Creek, **PNM**. Samples are referred to by the season in which they were obtained; sampling dates are presented in Table 4-16. Five replicate samples were taken at each site on each date. Four seasonal samples at both sites were originally planned. Surber bottom samples were collected in June 1989 (summer), October 1989 (autumn), and April 1990 (spring). The January (winter) sample was not taken because of ice cover.

4.5.1 Results

A total of 25 taxa were identified from the Surber samples taken from Pipestone Creek. At both sites the summer samples contained the most number of taxa (Fig. 4-27, Table 4-17). The number of qualitative EPT taxa were low (Fig. 4-27, Table 4-17). These pollution sensitive orders were absent from site 1 during the spring sampling period. No Plecoptera (stoneflies) were found during the 1989-1990 study period, suggesting past perturbations may have eliminated this sensitive group.

Mean density estimates over the sampling period were 1238 individuals/m^2 at Site 1 and 1969 individuals/m^2 at Site 2 (Fig. 4-28, Table 4-18). The highest densities were recorded during the summer sampling period at both sites. These high numbers were attributable primarily to the high densities of Trichoptera (caddisflies) and Diptera (fllies) (Tables 4-19, 4-20). The net-spinning caddisflies Cheumatopsyche and Hydropsyche were the most abundant Trichoptera, and the midge tribe Chironomini and black fly Simulium were the major Diptera in the summer (Table 4-21). Oligochaeta and Coleoptera were the only other groups that comprised > 10% of the individuals in any sample (Table 4-20).

Both the Shannon diversity and complement of Simpson's diversity index indicated similar trends in community diversity values (Fig. 4-29, Table 4-22). The highest diversity values were recorded in the summer and autumn at both sites. The highest value was in autumn at site 2. This value resulted from a sample with few individuals and a low number of taxa where the individuals were relatively evenly spread among the taxa. Lowest diversity values were in the spring when orthoclad midges composed over 50% of the individuals at both sites.

4.5.2 Ephemeroptera (Mayflies)

Stenacron interpunctatum (Say) can be an abundant mayfly in streams of the eastern half of North America (Lewis 1974). Ecological attributes of this species have been described by Wodsedalek (1912), McCafferty and Huff (1978), and Lamp and Britt (1981). Nymphs graze on the underside of rocks and large detritus

during the daytime in reaches of slower current (Lyman 1945, Lamp and Britt 1981). McCafferty and Huff (1978) and McCafferty and Periera (1984) indicated that this species had at least 2 or 3 broods at different degrees of maturity at any time of the year in Indiana. Emergence of adults occurs throughout the summer. At Pipestone Creek densities were highest in June. Lewis (1974) indicated this species can tolerate organic enrichment, and is often found below sewage treatment plants. Stenacron densities were highest in the summer with 136 and 228 individuals/m^2 at Sites 1 and 2, respectively.

4.5.3 Trichoptera (Caddisflies)

Thirteen species of Trichoptera in 6 families were identified from quantitative and qualitative collections at **PIPE** (Appendix A.3), and the immature stages of the family Hydropsychidae were a major component of the benthic fauna numerically. The ability of larvae to secrete silk has allowed them to exploit a wide range of lentic and lotic habitats (Mackay and Wiggins 1979). This success in habitat partitioning has produced much taxonomic richness, reflected in various types of fixed retreats, capture nets, and portable cases.

The Hydropsychidae are unquestionably the most diverse family of net-spinning caddisflies living in streams and rivers. At least 5 species have been collected from Pipestone Creek (Appendix A.3). Both Cheumatopsyche and Hydropsyche were most common during the summer sampling period, averaging over 600 individuals/m^2 at Site 2, while at Site 1 Hydropsyche numbered nearly 500 individuals/m^2

and *Cheumatopsyche* over 200 individuals/m^2 (Table 4-21).

4.5.4 Diptera (True Flies)

The abilities of Diptera to capitalize upon any available food items, combined with their great reproductive capacity and short life cycles, have led them to thrive under a variety of conditions and to predominate in many freshwater aquatic habitats. The Chironomidae (midge family) are an outstanding example. Species within the family exhibit a wide range of feeding habits and life cycles, and Pinder (1986) noted that few species appear restricted to one feeding method. Over the sampling season the family comprised 30% of the individuals at both sites. The tribe Chironomini reached its greatest abundance at Site 2 in summer, with over 1000 individuals/m^2 and the subfamily Orthocladiinae had its highest abundance at Site 2 in spring, over 500 individuals/m^2 (Table 4-21).

In many parts of the world, black flies (Simuliidae) are among the most serious pests of man and other homeothermic animals. Ecologically, larvae of most species feed by using an elaborate pair of labral fans to capture organic particles suspended in the water column, and thereby, have an important role in nutrient cycling in streams (Merritt and Wallace 1981). Larval period may last 3 to 4 weeks or up to 4-5 months for species that overwinter. Densities of *Simulium* larvae and pupae were highest in the summer, 523 individuals/m^2 (22% of the individuals) at Site 1, and 880 individuals/m^2 (18% of the individuals) at Site 2 (Table 4-21).

4.5.5 Functional Analysis

Collector-gatherers and collector-filterers dominated the functional feeding groups, comprising over 70% of the fauna at each site over the sampling period (Fig. 4-30, Table 4-23). The highest relative abundances of collector-gatherers were in the autumn and winter (Fig. 4-31, Table 4-23). The most abundant collector-gatherer taxa were the chironomid midges, Orthocladiinae and Chironomini, and the aquatic worms, Oligochaeta. In the summer, collector-filterers comprised 45% and 38% of the community at Sites 1 and 2, respectively. They had high relative abundance (35%) again at Site 2 in the spring. The net-spinning caddisfly genera *Cheumatopsyche* and *Hydropsyche*, and the black fly genus *Simulium* were major collector-filterers.

In the summer, scrapers comprised 10% of the community at Site 1 and 13% at Site 2, while in the spring they contributed 19% of the individuals at Site 1 (Fig. 4-31, Table 4-23). The mayfly *S. interpunctatum* and the riffle beetle *Stenelmis* were the most abundant scraper taxa.

Predators usually comprised around 10% of the community (Fig. 4-31, Table 4-23). The flatworm *Dugesia*, Tanypodinae midges, and the biting midges, Ceratopogonidae, were the most common predator taxa. Shredder taxa occurred at conspicuously low numbers.

Despite Site 2 being below a lake, no substantial differences were noted in macroinvertebrate trophic relationships from the upstream Site 1. Generally, macroinvertebrate species composition and trophic relationships are altered below reservoirs and lakes

for two reasons: (1) conditions are found to be unfavorable for certain species and these species are eliminated (fewer taxa), and (2) conditions are found to be particularly favorable for one or two species which increase dramatically, resulting in high dominance (Ward and Stanford 1979). Collector-filterer feeding groups such as net-spinning caddisflies, black flies and certain chironomid midges often dominate both in number and biomass below reservoirs and lakes (Wallace et al. 1977). In Pipestone Creek, site 2 had higher densities of these groups.

4.5.6 Summary of Benthic Macroinvertebrate Data

The taxa identified from **PNM** during the course of this study are presented in Appendix A.3. The macroinvertebrate community existing in Pipestone Creek appears to be atypical of smaller Northern prairie streams (see Neel 1985). The complete absence of stoneflies indicates that previous perturbations may have had a significant effect on this stream. Additionally, fewer mayfly taxa than expected were collected from a stream of this size. Also it would appear that no substantial recolonization sources are present nearby to help reintroduce species which were previously eliminated. Lake Hiawatha seems to have minimal effect on species abundance, diversity, and trophic relationships downstream in Pipestone Creek.

4.6 *Herbert Hoover National Historic Site*

A Surber square-foot bottom sampler (Fig. 4-1) was used to obtain seasonal samples at one study site on West Branch Wapsononoc Creek, **HEHO**. Samples are referred to by the season in which they were obtained; sampling dates are presented in Table 4-25. Five replicate samples were taken at the site on each date. Four seasonal samples at both sites were originally planned. Surber bottom samples were collected in June 1989 (summer), October 1989 (autumn), and April 1990 (spring). The January (winter) sample was not taken because of ice cover.

4.6.1 Results

A total of 26 taxa were identified from the Surber samples taken from West Branch Wapsinonoc Creek. Summer and autumn samples had the greatest number of taxa (Fig. 4-32, Table 4-25). The number of the pollution-sensitive EPT was low, only 4 collected during the sampling period.

Density of macroinvertebrates was found to be highest in summer, nearly 4000 individuals/m^2, whereas the number of individuals in spring sample was only about 300/m^2 (Fig. 4-33, Table 4-25). Diptera was by far the most abundant group of macroinvertebrates in West Branch Wapsononoc Creek, accounting for at least 60% of the numbers in every sample, with a mean of 68% of all the individuals collected during the whole sampling period (Table 4-26). Only three other groups were numerically important over the sampling season. Isopoda (aquatic sow bugs), Gastropoda (snails), and Oligochaeta (aquatic worms) accounted for 14%, 12%,

and 6% of the individuals, respectively (Table 4-26).

The low diversity values indicated that the benthic macroinvertebrate community of West Branch Wapsinonoc Creek appeared impacted (Fig. 4-34, Table 4-27). The Shannon diversity index and complement of Simpson's index indicated similar trends in community diversity values. Diversity values were highest in the summer and lower in the other seasons.

4.6.2 Diptera (True Flies)

The Chironomidae (midge family) (see section 4.5.4) was a major component of the fauna of West Branch Wapsinonoc Creek. In this study chironomid larvae were identified to subfamily, and to tribe in the Chironominae subfamily. In the summer the tribe Tanytarsini (primarily filter feeders) was the most abundant chironomid group (380 individuals/m^2, about 10% of the sample) (Table 4-28). Orthocladiinae (collector-gatherers) were the single most numerous taxon overall in autumn and spring. In autumn the number of orthoclad individuals was 1400/m^2 (66% of the sample), and in spring 179/m^2 (57%) (Table 4-28). Many species of this subfamily are cool season forms (Soponis 1977).

Larvae of the black fly Simulium (Simuliidae) (see section 4.5.4) were especially abundant in summer with over 2000 individuals/m^2, making up over 50% of the organisms in the sample (Table 4-28). Interestingly, five species and species complexes of Simulium were identified from West Branch Wapsinonoc Creek in this study.

4.6.3 Oligochaeta (Aquatic Earthworms)

Oligochaeta (see section 4.3.8) were consistently present in the benthic macroinvertebrate samples. They comprised between 4% and 7% of the fauna and their greatest density was 260 individuals/m^2 in summer (Tables 4-26, 4-28).

4.6.4 Isopoda (Aquatic Sow Bugs)

The vast majority of Isopoda (also known as pill bugs and sow bugs) species are terrestrial and marine. Freshwater species are found in small streams, springs, ponds, and other specialized habitats. Like the common terrestrial "pill bug" they are found in dark areas, under rocks and debris. There are about 130 freshwater species in the United States, although the taxonomy is poorly known. Isopoda are known as scavengers and are classified as shredders in this study (Pennak 1989). Some species of Isopoda are found very abundantly in "recovery" zones of streams receiving point-source organic enrichment (Hellawell 1986, Pennak 1989).

The genus Caecidotea was found abundantly throughout sampling in this study, comprising between 11% and 31% of the individuals in individual samples and averaged 200 individuals/m^2 over the study season (Tables 4-26, 4-28). The name Asellus has been used for this genus in the past, but Caecidotea is being more frequently accepted for this genus (Pennak 1989). Some species of Isopoda are found very abundantly in "recovery" zones of streams receiving point-source organic enrichment (Hellawell 1986, Pennak 1989).

4.6.5 Gastropoda (Snails, Limpets)

Snails in the family Physidae were common in benthic samples. Physid snails generally feed on the algae covering solid submerged substrates and are considered scrapers in this study. The physid snail *Physella* was most abundant in the summer sample with over 700 individuals/m^2, and comprised 18% of the numbers (Tables 4-26, 4-28).

4.6.6 Functional Analysis

The major taxonomic groups found in West Branch Wapsinonoc Creek represent several functional feeding groups. In the summer, collector-filterers, composed primarily of *Simulium* and Tanytarsini midges comprised 60% of the fauna. The scrapers represented about 19% of the community, which was primarily the physid snail *Physella*. The isopod *Caecidotea* (=*Asellus*), a shredder represented 11% of the fauna numerically. Collector-gatherers, mostly Orthocladiinae, were the dominant group in autumn and spring, 72% and 63% respectively (Fig. 4-35, Table 4-29). The shredders (exclusively *Caecidotea*) comprised 17% and 31% of the autumn and spring communities. During the whole sampling season small particle detritivores (collector-filterers, collector-gatherers) combined represent 72% of the faunal numbers (Fig. 4-36, Table 4-29).

4.6.7 Summary of Benthic Macroinvertebrate Data

The benthic community of West Branch Wapsinonoc Creek reflects historical and present point and non-point source pollution. The upper watershed is impacted by agriculture and the lower portion by

urban impacts such as road and parking lot runoff and intermittent discharge from businesses. The community is dominated by only a few taxa. The species of macroinvertebrates inhabiting the streams include typical resilient forms (Chironomidae, Physidae, Oligochaeta) and species able to rapidly recolonize the stream from other sources (Simuliidae, Chironomidae). Because of the continued impacts mentioned above and sporadic spates, the benthic macroinvertebrate community will remain simple and not reflect former natural conditions.

4.7 *George Washington Carver National Monument*

A Surber square-foot bottom sampler (Fig. 4-1) was used to obtain quarterly samples at Carver Branch and Williams Branch. Samples are referred to by the season in which they were obtained; sampling dates are presented in Table 4-30. Five replicate samples were taken at each site on each date.

4.7.1 Results

Over the sampling year 75 taxa were identified from benthic samples, 61 were found on Carver Branch and 66 on Williams. At both sites the most taxa were identified in the spring samples, and the least in the autumn samples (Fig. 4-37, Table 4-31). The number of qualitative EPT taxa are presented in Fig. 4-37, and Table 4-31.

Mean density estimates over the sampling period were 3603 individuals/m^2 at Carver and 5618 individuals/m^2 at Williams (Table 4-32). The highest densities were recorded on the winter date at both sites (Fig. 4-38).

Over the sampling year Diptera was the most abundant group, comprising 58% and 57% of the individuals at Carver and Williams, respectively (Tables 4-33, 4-34). The midge family Chironomidae accounted for most of the Diptera. Trichoptera and Turbellaria were the next most abundant groups. The composition of the communities varied with the season.

The summer sample at Carver had four groups constituting between 15% and 29% of the individuals. These were Trichoptera (29%), Plecoptera (22%), Odonata (15%), and Diptera (15%). In the other three Carver seasonal samples Diptera were the most abundant group with 91% of the individuals in autumn, 49% in winter, and 68% in spring. In the winter sample, Turbellaria and Pelecypoda individuals each made up 10% of the sample. No other groups comprised 10% or more of a sample, although Trichoptera represented 9% of the individuals in both winter and spring.

At Williams in the summer sample five groups comprised between 15% and 22% of the individuals. Theses were Diptera (22%), Coleoptera (18%), Trichoptera (16%), Amphipoda (16%), and Turbellaria (15%). These groups were usually the most abundant in the other samples as well. Diptera were the most abundant group in the three other seasonal samples, constituting 51% of the individuals in the autumn, 78% in the winter, and 43% in the spring. In the Williams autumn sample the same groups were abundant, Trichoptera (11%), Turbellaria (11%), Amphipoda (10%), and Coleoptera (9%). In the winter sample Trichoptera (14%) was the only group relatively well represented in addition to Diptera.

Finally, in the spring sample, Turbellaria (21%), Amphipoda (13%) and Trichoptera (9%) were major contributors.

Both the Shannon diversity and complement of Simpson's diversity index indicated similar trends in community diversity values (Fig. 4-39, Table 4-35). The highest diversity values were recorded in the summer sample at both sites. Carver had an extremely low diversity value in the autumn sample, while Williams had its lowest diversity value in the winter.

4.7.2 Odonata (Dragonflies, Damselflies)

Little biological information is presently available on the numerous species included in the wide ranging genus *Argia*. Adult females usually oviposit in submerged wood. Nymphs apparently overwinter in various instars and can be found under stones and bottom debris. Adults fly from June through September. Nymphal density of *Argia plana* at Carver peaked during the summer and was stable throughout the remainder of the sampling period (Fig. 4-40). At Williams the highest density was found in the winter sample. Bick and Bick (1968, 1972) provide additional information on this species.

4.7.3 Plecoptera (Stoneflies)

Plecoptera were represented by ten species in six families from qualitative collections (Appendix A.5). Many Ozark stream support a diverse stonefly species assemblage (Poulton and Stewart 1991).

Zealeuctra claasseni was the most common stonefly in benthic samples, being especially abundant in the summer Carver sample

(density = 278 individuals/m^2). This winter or fall stonefly species ranges from Oklahoma to eastern Texas, northeastward across the Ozarks into the Appalachian plateaus of Tennessee, Kentucky and West Virginia, and northward along the Ohio Valley in southern Illinois and Indiana. Adults emerge from November to early March. Snellen and Stewart (1979) studied the life cycle of this species in an intermittent stream in eastern Texas. Adults usually emerged over a 6-8 week period. Oviposition occurred 1 to 2 days after emergence. The Texas populations apparently exhibit four growth patterns, depending on stream conditions: 1) slow univoltine; 2) fast univoltine, with short egg diapause and rapid larval growth during declining fall water temperatures; 3) fast univoltine, with a long egg diapause for 1 or more years, followed by a breaking of diapause in fall, and rapid 3-4 month larval growth; and 4) slow semivoltine, with slow larval growth during warm seasons. *Zealeuctra claasseni* in Carver Branch appear to be either slow univoltine or fast univoltine (Fig. 4-41).

4.7.4 *Trichoptera (Caddisflies)*

Fifteen species of Trichoptera (see section 4.5.3) in ten families were identified from **GWCNM** during this study (Appendix A.5), and the immature stages of this order were a major component of the benthic fauna numerically. The trichopteran fauna of the **GWCA** reflect this taxonomic and functional diversity of this order.

Three species of the family Hyropsychidae were collected in the **GWCA** (Appendix A.5). The most common species appears to be *Cheumatopsyche pettiti* (Banks) a species known from across North

America. Cheumatopsyche pettiti occurs over a wide range of habitats and can tolerate organically enriched and silty conditions. Anderson (1976) summarizes present knowledge of this species. This species is probably univoltine in the **GWCA**. At both sites populations were highest during the winter (Fig. 4-42).

Helicopsyche borealis (Hagen) has a transcontinental distribution and is unique among North American caddisflies because the larval case is made in the form of a helix and looks like a small snail. This species occurs in a variety of streams ranging from pristine to moderately polluted. The biology and zoogeography of this species was reviewed by Williams et al. (1983). At both study sites H. borealis is univoltine with emergence in late June and July. All instars could be collected by the winter sampling period (Fig. 4-43). Maximum density occurred in the Carver winter sample, whereas at Williams maximum density was in the autumn sample.

Chimarra aterrima Hagen is widely distributed throughout the eastern half of North America (Lago and Harris 1987) and prefers small cool streams. The univoltine life cycle has been described by Williams and Hynes (1973). Larvae are present throughout the year and rapid growth occurs during the summer. Growth is slow during the cooler months of the year. Population increases are often dramatic during this time and early summer which appears to be the case at Williams (Fig. 4-44). Peak emergence of adults is in June.

4.7.5 Coleoptera (Beetles)

Over 5000 aquatic Coleoptera species have been identified, are found in a variety of habitats (White et al. 1984). Eleven species in five families were identified in this study. The genera *Stenelmis* and *Optioservus* of the family Elmidae were the most common beetles in the Surber samples. Members of this family are commonly known as riffle beetles, and several genera in this family are commonly collected in benthic riffle samples, sometimes in large numbers. Larvae are completely aquatic. The larval stage lasts from 6-36 months, depending on temperature and food availability, and pupate in moist sites above water level (Brown 1987). Adults elmids are aquatic, although most species have an initial flight after emergence. Riffle beetles have been used as indicators of water quality, but sensitivity to pollution varies depending on individual species and type of pollution (Sinclair 1964, Weber 1973). *Stenelmis* and *Optioservus* larvae were most abundant at Williams in summer, while at Carver both genera were abundant only in winter Fig. (4-45).

4.7.6 Diptera (True Flies)

The Chironomidae (see section 4.5.4) family reached densities over 3600 individuals/m^2 at Carver and over 8800 individuals/m^2 at Williams (both in winter) (Fig. 4-46); over the year the family comprised 54% of the individuals collected at Carver and 56% at Williams. The chironomid subfamily Orthocladiinae, and Tanytarsini tribe of the subfamily Chironominae were especially abundant.

At both sites *Simulium* species (Simuliidae, black flies) (see section 4.5.4) were apparently spring emerging species. At this

time highest densities can be recorded (Fig. 4-47).

4.7.7 Turbellaria (Flatworms)

Turbellarians occupy a wide variety of aquatic habitats including springs, ponds, and small streams. *Dugesia* is a common genus widespread over North America. *Dugesia* (probably *D. doratocephala*) was abundant throughout the year at Carver with peak density of 792 individuals/m^2 in summer (Fig 4-48). At Williams, *Dugesia* reached its peak density in winter, 721 individuals/m^2 sample.

4.7.8 Functional Analysis

Over the whole sampling season collector-filterers were the most abundant functional group at both Carver, an average of 44% of the individuals, and Williams, 48% of the individuals (Fig. 4-49, Table 4-36). At Carver they made up the greatest proportion of the community in the autumn sample (78%), and at Williams they made up 72% of the community in winter (Fig. 4-50, Table 4-36). Collector-filterers were at their lowest proportion in spring at both sites. Tanytarsini midges, the caddisfly *Cheumatopsyche*, the blackfly *Simulium*, and the Sphaeriidae fingernail clams were all numerically important in this study.

Collector-gatherers were the second most abundant functional group at both sites, comprising 28% of the communities (Fig. 4-48, Table 4-36). The highest collector-gatherer relative abundance was in the spring at both Carver (61%) and Williams (43%) (Fig. 4-50, Table 4-36). Orthocladiinae midges and Amphipoda were the most abundant collector-gatherers in this study.

Scrapers made up 9% of the fauna at both Carver and Williams over the year (Fig. 4-49, Table 4-36). Several scrapers reached high abundances in various times during the sampling period. In summer at Carver the mayfly Habrophlebiodes americana (Banks) and the larvae of the water-penny beetle Psphenus herricki (DeKay) had densities of over 40 individuals/m^2 each (combined 7% of the individuals), and at Williams the elmid beetles Stenelmis and Optioservus larvae and adults had a combined density of over 900 individuals /m^2 (18% of the individuals). Helicopsyche borealis was most abundant at Williams in autumn (153 individuals/m^2, 4% of the individuals) and at Carver in winter (316 individuals/m^2, 4% of the individuals). Additionally, Gastropoda (snails) were also present throughout the sampling period.

Shredders had surprisingly low relative abundance in benthic samples except for Zealeuctra claasseni in the summer at Carver. Predators ranged in relative abundance from 4% to 26% (Table 4-36, Fig. 4-50). Eighteen taxa were classified as predators in this study. The most common over the sampling period were Dugesia, Acarina, and the Chironomidae subfamily, Tanypodinae.

4.7.9 Summary of Benthic Macroinvertebrate Data

The taxa identified from **GWCA** during the course of this study is presented in Appendix A.5. The macroinvertebrate community existing presently in the streams of **GWCA** are typical of smaller streams of the Ozark Highlands (i.e. Cather and Harp 1975, Dieffenbach and Ryck 1976, Ernst and Stewart 1986). Number of taxa (Table 4-32) and densities (Table 4-33) are reflective of the

habitat available and yearly flow patterns.

The predominance of the two collector groups indicate that the food base in the streams is FPOM. The low number of shredders in the streams is surprising, since the streams are partially canopied. The intermittent nature of the streams may account for the low numbers of shredder taxa.

4.8 *Wilson's Creek National Battlefield*

A Surber square-foot bottom sampler (Fig. 4-1) was used to obtain four samples/year at the three study sites in the **WICR.** Sampling dates are presented in Table 4-37. Five replicate samples were taken at the site on each date. Sampling was conducted bimonthly from April through October for two years (Table 4-37). Eight sets of samples were obtained during this study beginning April 1988 and ending October 1990.

4.8.1 <u>Results</u>

Overall, 64 taxa were identified from Wilson Creek and 66 taxa from Skeggs Branch during quantitative macroinvertebrate sampling. Of these 12, 11, and 23 were EPT taxa at Wilson Upper, Wilson Lower and Skeggs, respectively. The average number of taxa collected in a single sample was 24 at both Wilson sites and 36 taxa at Skeggs, with an average of 5 EPT taxa at each of the Wilson sites and an average of 11 EPT taxa/sample at Skeggs. The number of taxa collected were especially low in April 1990 at the Wilson Site but at its highest at Skeggs on the same date (Fig. 51).

Macroinvertebrate density averaged 14,861/m^2 at Wilson Upper, 13,287/m^2 at Wilson Lower, and 7848/m^2 at Skeggs (Table 38).

Density was extremely high at each of the Wilson sites in October 1989 and June 1990, and very low in April 1990 (Fig. 52). At Skeggs there was no great increase in density during October 1989 and June 1990, or decrease in April 1990 as seen at both Wilsons sites. Macroinvertebrate density at Skeggs followed the same trends in the first and second sets of four samples, although during the second set all density values were higher. April samples had the highest densities in each set of four.

The Wilson Creek sites were similar in their composition. Over the sampling period Diptera were the most abundant group comprising 65% of the individuals at Wilson Upper and 66% at Wilson Lower (Table 39). Ephemeroptera (mayflies) and Oligochaeta (aquatic worms) were the other groups that composed over 10% of the individuals over the sampling period at these sites. These two sites differed in the next most abundant groups, with Trichoptera (caddisflies) and Coleoptera (beetles) consistently comprising a greater percentage of the fauna and being more abundant at Wilson Lower. Conspicuously few Plecoptera (stoneflies) were collected from Wilson Creek.

Skeggs Branch had a more diverse community than Wilson Creek, but still was dominated by relatively few groups. Diptera (true flies) (44%), Isopoda (sow bugs) (16%), Ephemeroptera (10%), Trichoptera (8%), and Oligochaeta (8%) had the greatest numbers of individuals (Table 4-39).

Shannon and Simpson diversity indices also indicated that Skeggs was a more diverse community (Fig 4-53). Both April samples

at the Wilson sites had low diversity values. Interestingly, in April 1990, even though Skeggs did not have a very low density as at the Wilsons sites, the diversity indices indicated a lower than average diversity.

4.8.2 Ephemeroptera (Mayflies)

Ten Ephemeroptera species in 7 families were identified from qualitative and quantitative collections in **WICR**. Caenis latipennis Banks and Baetis spp. were the most common Ephemeroptera taxa occurring in quantitative samples at the Wilson Creek study sites and were periodically very abundant (Table 4-40). Baetis spp. was the most common Mayfly taxon at Skeggs, but there were 6 other Mayfly taxa that were routinely sampled, including Acentrella insignificans McDunnough, C. latipennis Banks, Eurylophella aestiva (McDunnough), Stenacron interpunctatum (Say), Stenonema femoratum (Say), Paraleptophlebia sp.

Caenis had its highest abundance in the October and August samples in Wilsons Creek (Table 4-40). At Wilson Upper, it had a density of over 8600 individuals/m^2 in October 1989. Caenis was present in low numbers in Skeggs collections.

Three species of Baetidae occurred in Wilson Creek and Skeggs Branch, Acentrella insignificans McDunnough, Baetis flavistriga McDunnough, and Diphetor hageni (Eaton). During this study, B. flavistriga and D. hageni were identified as Baetis spp. Until recently (Waltz and McCafferty 1987a, 1987b) these three species were classified in the genus Baetis. McCafferty and Waltz (1990) review systematics changes in the family Baetidae. At Wilson Upper

Baetis spp. had a density of over $1000/m^2$ on three sampling dates (Table 4-5). Baetis spp. were usually less common downstream at Wilson Lower. Baetis spp. were present in every sample, but occurred at less variable densities than at Wilson Creek sites. At Skeggs Baetis spp. averaged 539 individuals/m^2 ranging from 41 - $1841/m^2$.

4.8.3 Plecoptera (Stoneflies)

Plecoptera were conspicuous by their relatvie absence in benthic samples. Only one stonefly taxon was identified from benthic samples at Wilson Upper (Zealeuctra claasseni (Frison), 1 individual collected), and Wilson Lower (Agnetina flavescens (Walsh), 2 individuals collected) (Table 4-40). These species may have originated from other nearby streams. Ozark highlands streams typically have a very high diversity of stoneflies (Poulton and Stewart 1991). At Skeggs, five stonefly taxa were identified from benthic samples. Agnetina flavescens and Zealeuctra claasseni were the most common taxa. Amphinemura delosa, Perlesta sp., and Clioperla clio (Newman) were also present. Adults of a number of other species came to a light trap in June 1989 (Appendix A.6). However, immatures were not collected from the stream.

4.8.4 Trichoptera (Caddisflies)

Species in seven families of Trichoptera (see sction 4.5.3) were identified from **WICR** during this study (Appendix A), but the immature stages were less abundant than expected in the quantitative samples. Two genera in the Hydropsychidae family, Cheumatopsyche and Hydropsyche, were commonly collected in Wilson

Creek and Skeggs Branch (Table 4-40). The genus Cheumatopsyche occurs over a wide range of habitats across North America and is known to be widely tolerant of pollution (Harris and Lawrence 1978). The tolerance of the Hydropsyche depends on the individual species, some being found in a wide range of conditions, while others are restricted to specific conditions.

Two genera, Hydroptilidae and Ochrotrichia in the family Hydroptilidae were periodically collected in large numbers in Skeggs Branch (Table 4-40). Pollution tolerances are not well known for species in this family.

4.8.5 Coleoptera (Beetles)

Fifteen species in six families were identified in this study from **WCNB**. The genera Stenelmis and Optioservus in the family Elmidae were the only common beetles in the Surber samples (see section 4.7.5). Stenelmis larvae and adults were commonly collected at both Wilson sites, but were nearly twice as abundant, both relatively and absolutely, downstream at Wilson Lower (Table 4-40). Optioservus was not often collected at Wilson Creek sites. Optioservus and Stenelmis were both commonly collected at Skeggs, but Optioservus was usually present in much larger numbers.

4.8.6 Diptera (True Flies)

The Chironomidae family (see section 4.5.4) was a major component of the fauna of Wilson Creek and Skeggs Branch. In this study chironomid larvae were identified to subfamily, and to tribes in the Chironominae subfamily. The midge subfamily Orthocladiinae was the most abundant taxon overall at all three sites averaging

6913/m^2 (47% of total mean density) at Wilson Upper, 5978/m^2 (45%) at Wilson Lower, and 2356/m^2 (30%) at Skeggs (Table 4-40). *Eukiefferiella* spp. and *Cricotopus* spp. appeared to be the most common genera. Taxonomy to species in the genus *Eukiefferiella* is difficult or impossible in North America, and often specimens are identified to a species group. Many groups are widespread and common (Bode 1983). LeSage and Harrison (1980) provide life history information on 15 species of *Cricotopus*. They found all *Cricotopus* multivoltine, with five generations per year. Peak emergences were in late spring, which is consistent with our large number of larvae in early spring. A number of species in these orthoclad genera are considered tolerant of enriched, polluted, and turbid water.

4.8.7 Oligochaeta (Aquatic Earthworms)

Oligochaeta (see section 4.3.8) were a major part of benthic communities at all sites, comprising 19% (2884/m2), 11% (1473/m2), and 8% (629/m2) of the individuals at Wilson Upper, Wilson Lower and Skeggs, repectively.

4.8.8 Isopoda (Aquatic Sow Bugs)

The genus *Lirceus* was a major component of the Skeggs Branch macroinvertebrate community (see section 4.6.4). Over the entire sampling period *Lirceus* averaged 16% of the individuals (1246/m^2), ranging from 7% (October 1988) to 35% (June 1989) in separate samples (Table 4-40). *Lirceus* density at Skeggs ranged from 239 (October 1988) to 2372 individuals/m^2 (April 1989).

4.8.9 Functional Analysis

Both Wilson sites were overwhelmingly dominated by collector-gatherers, averaging 81% at Wilson Upper and 75% at Wilson Lower (Fig. 4-54). Predators (7%) were the next most abundant group at Wilson Upper. Collector-filterers (11%) were the second most abundant group at Wilson Lower. On several occasions they comprised greater than 20% of the fauna (Fig. 4-55). Scrapers were also periodically abundant at Wilson Lower (Fig. 4-55)

Collector-gatherers made up 51% of the fauna at Skeggs. The shredder group was almost absent from the Wilson samples, but was a major component of the Skeggs community. The shredders averaged 16% of the fauna over all the samples (Fig. 4-54), ranging from 7% to 35% in individual samples at Skeggs (Fig. 4-55). The isopod _Lirceus_ was the only common shredder.

4.8.10 Summary of Benthic Macroinvertebrate Data

The diverse stream systems of the Ozark Highlands of southern Missouri were once known to process high species diversity and density of aquatic insects. For example, Sullivan (1933) observed that in the nearby James River "stone flies are found by the hundreds clinging to the rocks, especially _Acroneuria_ and _Perla_ (=_Agnetina_) and to a lesser extent _Perlinella_ and _Pteronarcys_. In the same environment, large numbers of Mayfly nymphs, including _Chirotenetes_ (=_Isonychia_), _Ecdyonurus_ (=_Stenonema_), _Potamanthus_ (=_Anthopotamus_), _Baetis_, _Blasturus_ (=_Leptophlebia_), _Epeorus_ and _Ephemerella_ are present, and in the sand and gravel the burrowing May fly, _Heptagenia_ (=_Hexagenia_) is encountered." However, many of these streams have been degraded historically and currently by

sewage effluents, discharges of industrial wastes, and agricultural runoff. As Aley and Aley (1988) have clearly summarized, Wilson Creek is such as stream.

The benthic macroinvertebrate community of Wilson Creek clearly indicates a stressed ecosytem. Plecoptera (stoneflies), considered to be extremely sensitive to organic enrichment and heavy metal pollution (Surdick and Gaufin 1978), were conspicuously absent or low in number from benthic samples. Additionally the diversity of mayflies was low for a stream of this geographical proximity and with a diversity of habitats available (Dieffenbach and Ryck 1976).

The EPT index utilizes three aquatic insect orders, Ephemeroptera, Plecoptera, and Trichoptera, which are comprised of many pollution-sensitive species. From all of the quantitative samples taken during the study, a total of only 12 and 11 EPT taxa were identified from each of the two Wilson Creek sampling sites (Table 4-40). There was an average of 5 EPT taxa per collection. The expected number of EPT taxa in a single sample from an Ozark stream is higher, probably between 18-22.

Wilhm (1970) surveyed data from a variety of streams and found that Shannon index, when caluculated with $\log_2$, gave values of >3 in clean streams and values of <1 in heavily polluted water. This study calculated the Shannon index with ln differing by a constant. Wilhm's clean water $\log_2$ Shannon value of 3 * 0.6931 yields a ln Shannon value of 2.1, and his polluted water value of 1 is equivalent to 0.69. Wilson Upper always had a Shannon (calculated with ln) value below 2.1, suggesting that the stream is perturbated

(Fig. 4-53). Shannon values were higher downstream at Wilson Lower on all but one occasion (April 1990). Skeggs consistently had values >2.1 except in April 1990. The authors of this report stress that diversity indices must be interpreted with caution because these indices do not consider qualitative species composition, for moderate disturbance may increase diversity, and because many communities have naturally low diversity. Many workers have warned that the biological relevance of diversity indices has not been determined.

There seems to be marginally better water quality at Wilson Lower when compared to the upstream site, because there is a more diverse benthic macroinvertebrate community. There was a greater relative abundance of sensitive groups such as Ephemeroptera, Trichoptera, and Elmidae (riffle beetles), and a lower abundance of Oligochaeta, which translated into greater diversity index values. The average number of taxa and EPT taxa at each of these sites were similar, however.

Large fluctuations in macroinvertebrate densities recorded on the last three sampling dates were difficult to explain. On 25 October 1989 and 27 June 1990 densities at Wilson Upper and Wilson Lower were much higher than average, and on 7 April 1990 densities were lower (Fig. 4-52, Table 4-38). These numbers may be related to stream discharge, but there are no current discharge records from Wilson Creek. U.S.G.S. flow records from nearby James Creek are not yet available for this time period. Historically there has been associated dramatic water quality changes related to high and

low discharge (Aley and Aley 1988). At high discharge, sewage sludge may be suspended into the creek, and during low flows up to 75% of the streamflow is treated water originating from the Southwest Wastewater Treatment Plant. Associated water quality parameters such as heavy metals and other toxicants from the sludge to elevated nutrients, etc. in the treated water are known to enhance population densities of certain macroinvertebrates and negatively effect other taxa (Hynes 1960).

The benthic macroinvertebrate community of Skeggs Branch contains many species typical of smaller Ozark Highland streams (i. e. Cather and Harp 1975, Dieffenbach and Ryck 1976, Ernst and Stewart 1986) and cannot be directly compared to Wilson Creek, a larger stream. However, the diversity and densities of the more sensitive EPT taxa were lower than expected (Fig. 4-51, Table 4-40), indicating probable continued effects of surface and groundwater contamination (Aley and Aley 1988) in Skeggs Branch.

Figure 4-1. Surber bottom sampler.

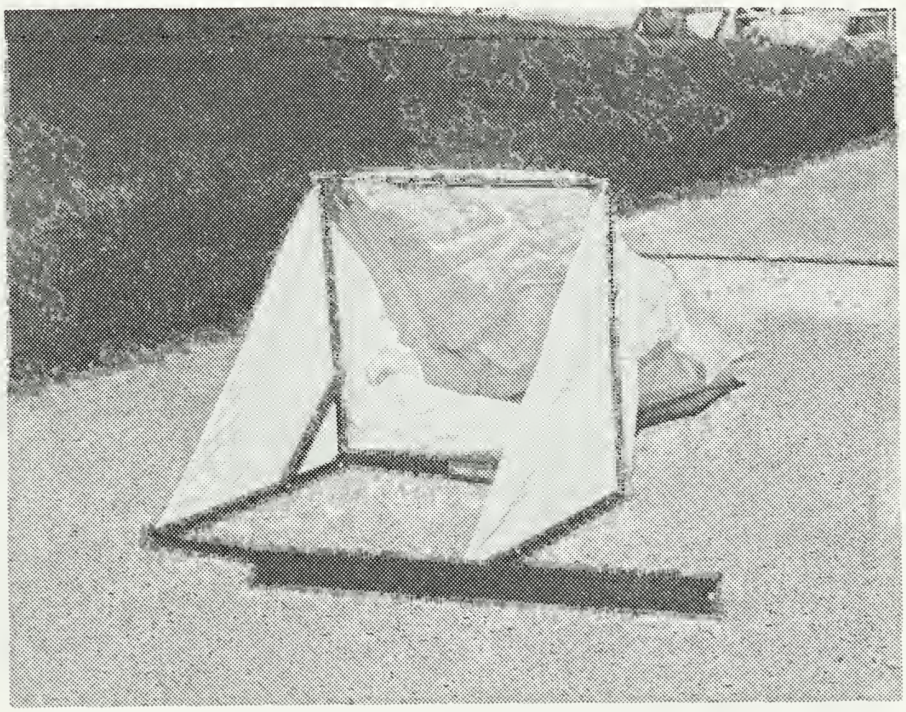


Fig 4-1

Figure 4-2. Hess bottom sampler.

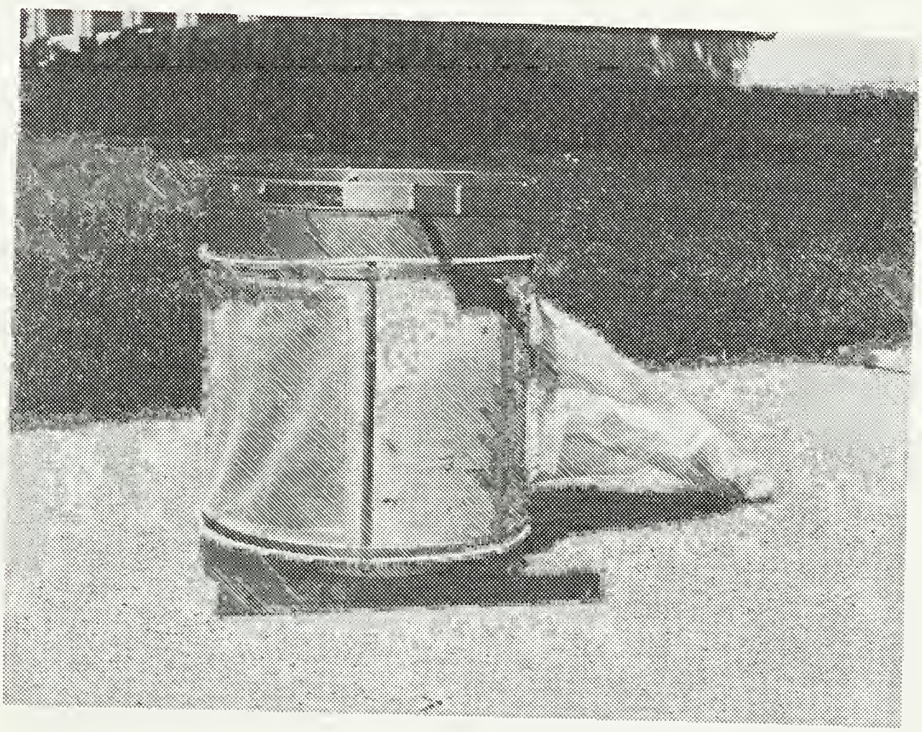


Fig 4-2

Figure 4-3. Hester-Dendy multiple plate sampler.

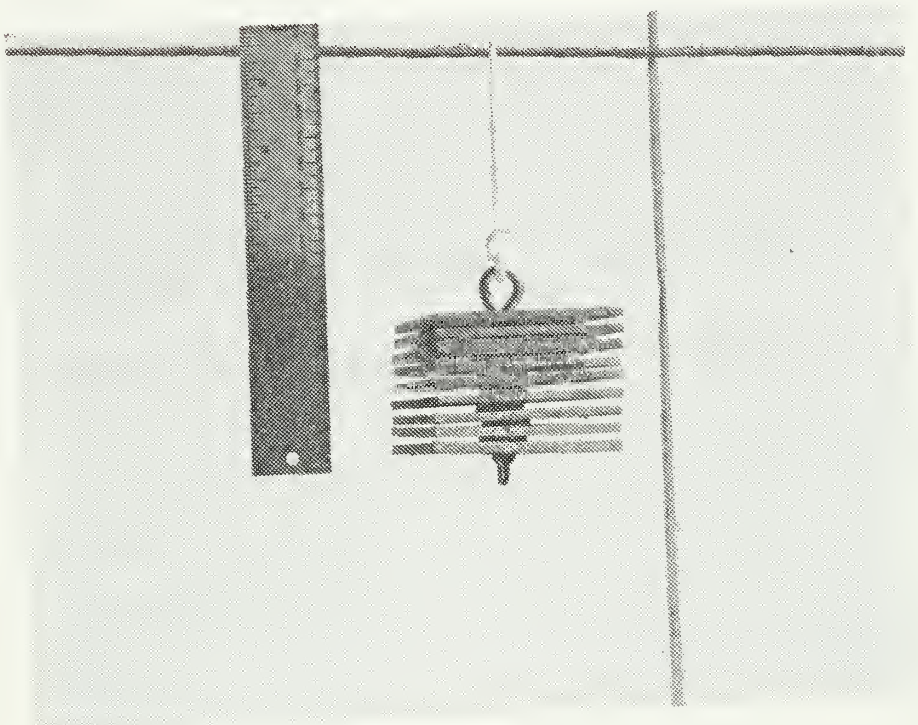
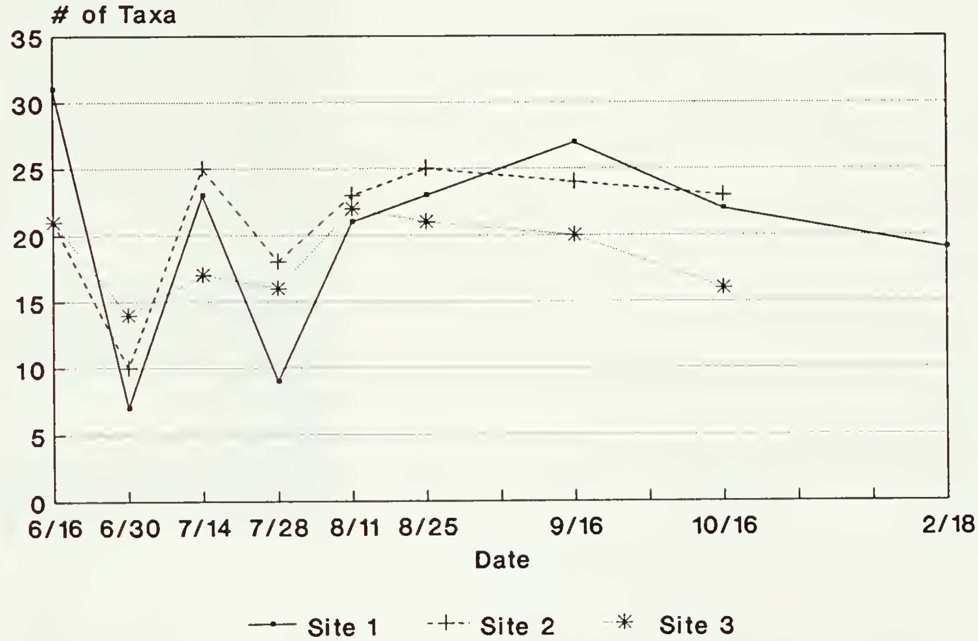
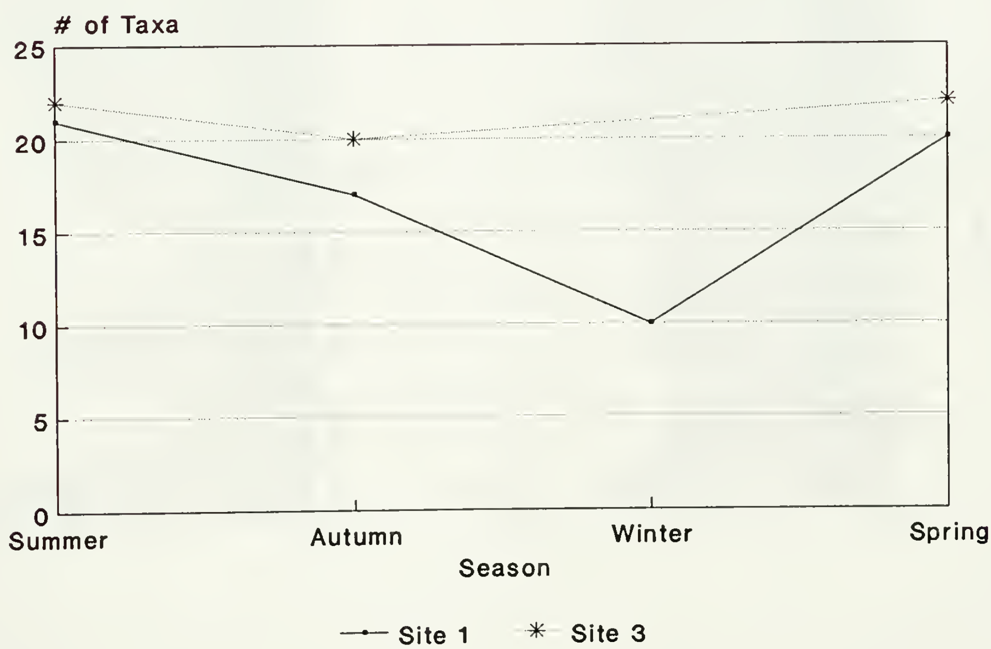


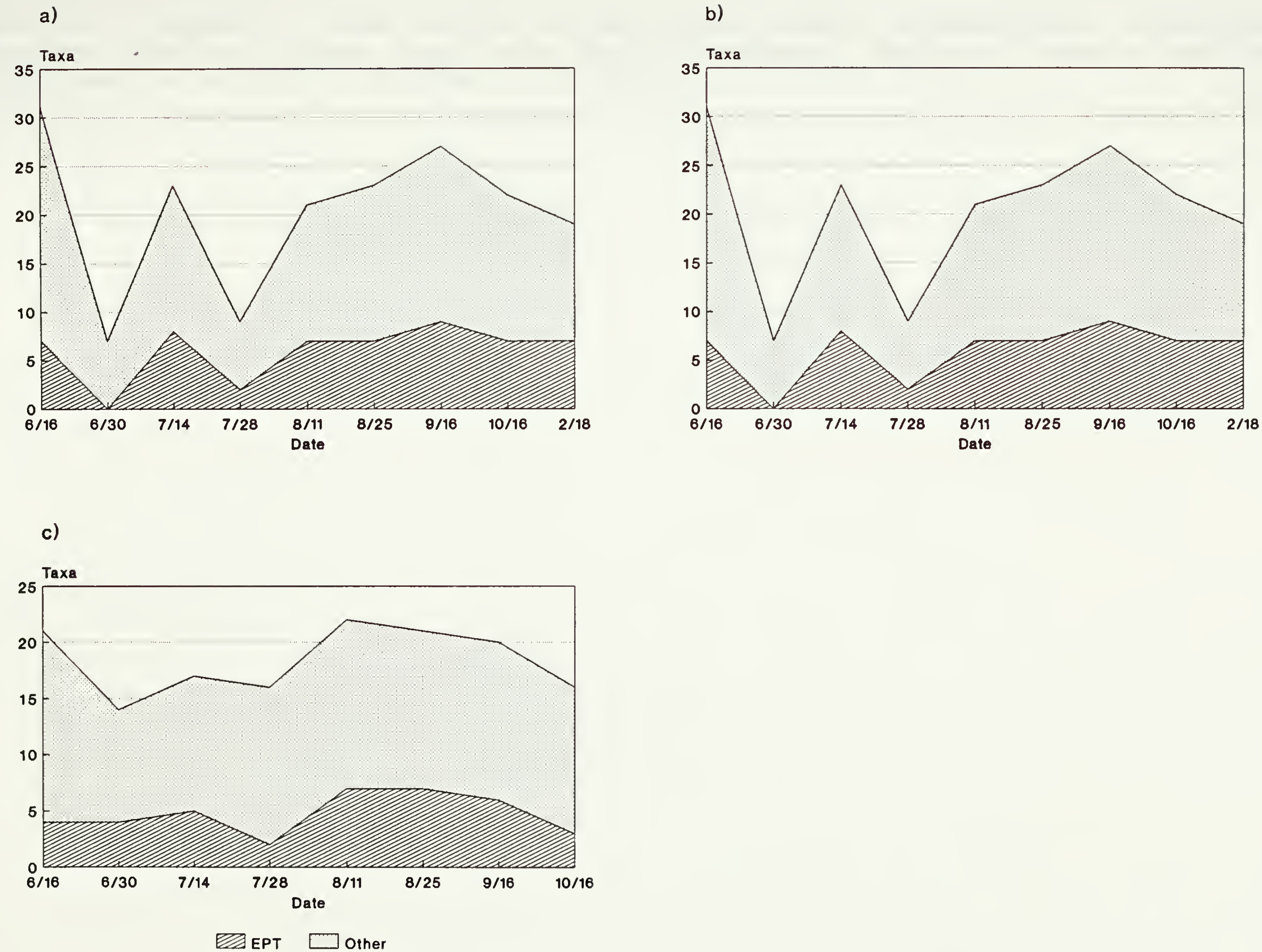
Figure 4-4. Number of macroinvertebrate taxa found on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

a)



b)



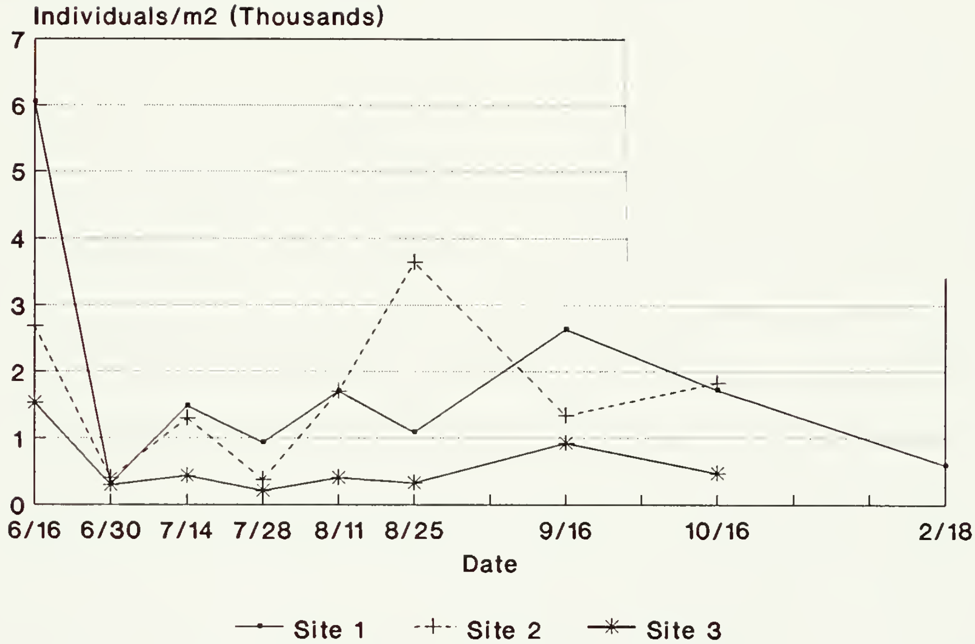


a)
Taxa
35
30
25
20
15
10
5
0
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
2/18
Date
b)
Taxa
35
30
25
20
15
10
5
0
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
2/18
Date
c)
Taxa
25
20
15
10
5
0
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
Date
EPT
Other

Figure 4-5. Number of taxa in one of the three orders: Ephemeroptera, Plecoptera, Trichoptera (EPT taxa), Agate Fossil Beds National Monument, Nebraska, found on each Hess sampling date for a) Site 1, b) Site 2, c) Site 3.

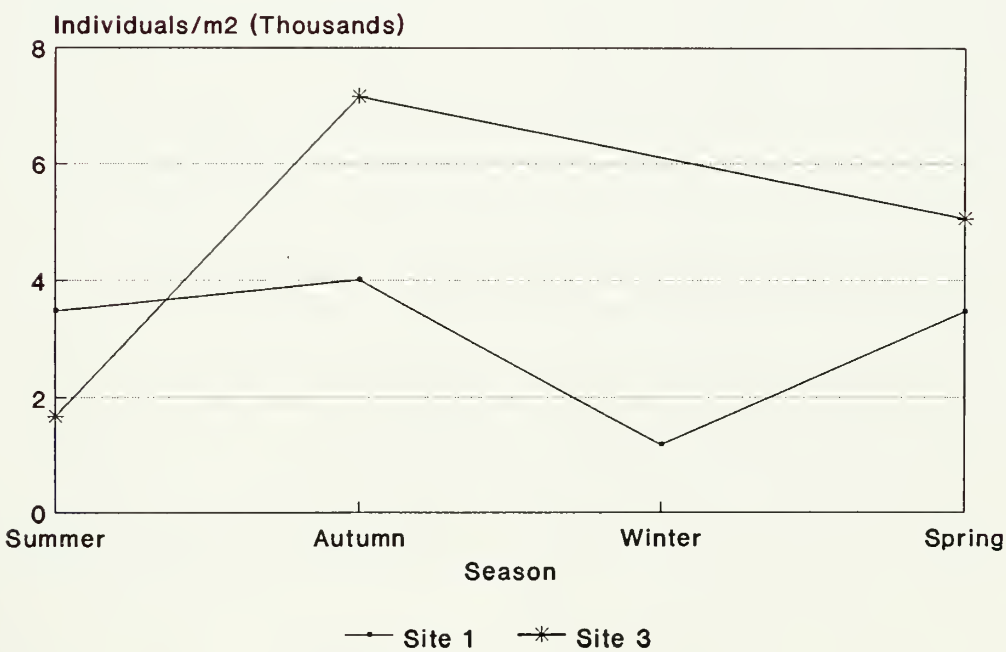
Fig 4-6

a)



Individuals/m2 (Thousands)
7
6
5
4
3
2
1
0
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
2/18
Date
Site 1
Site 2
Site 3

b)

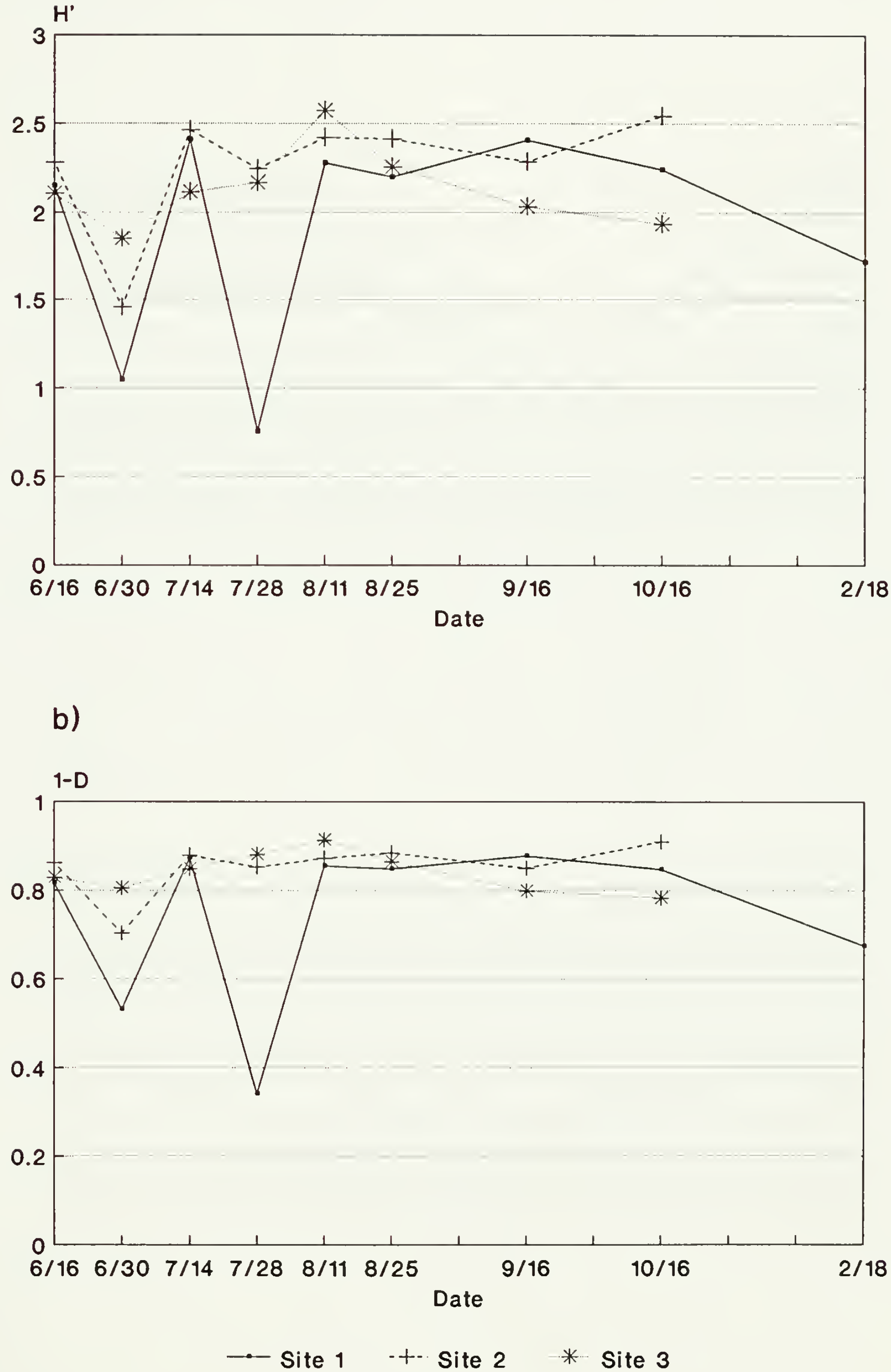


Individuals/m2 (Thousands)
8
6
4
2
0
Summer
Autumn
Winter
Spring
Season
Site 1
Site 3

Figure 4-6. Macroinvertebrate density on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

a)

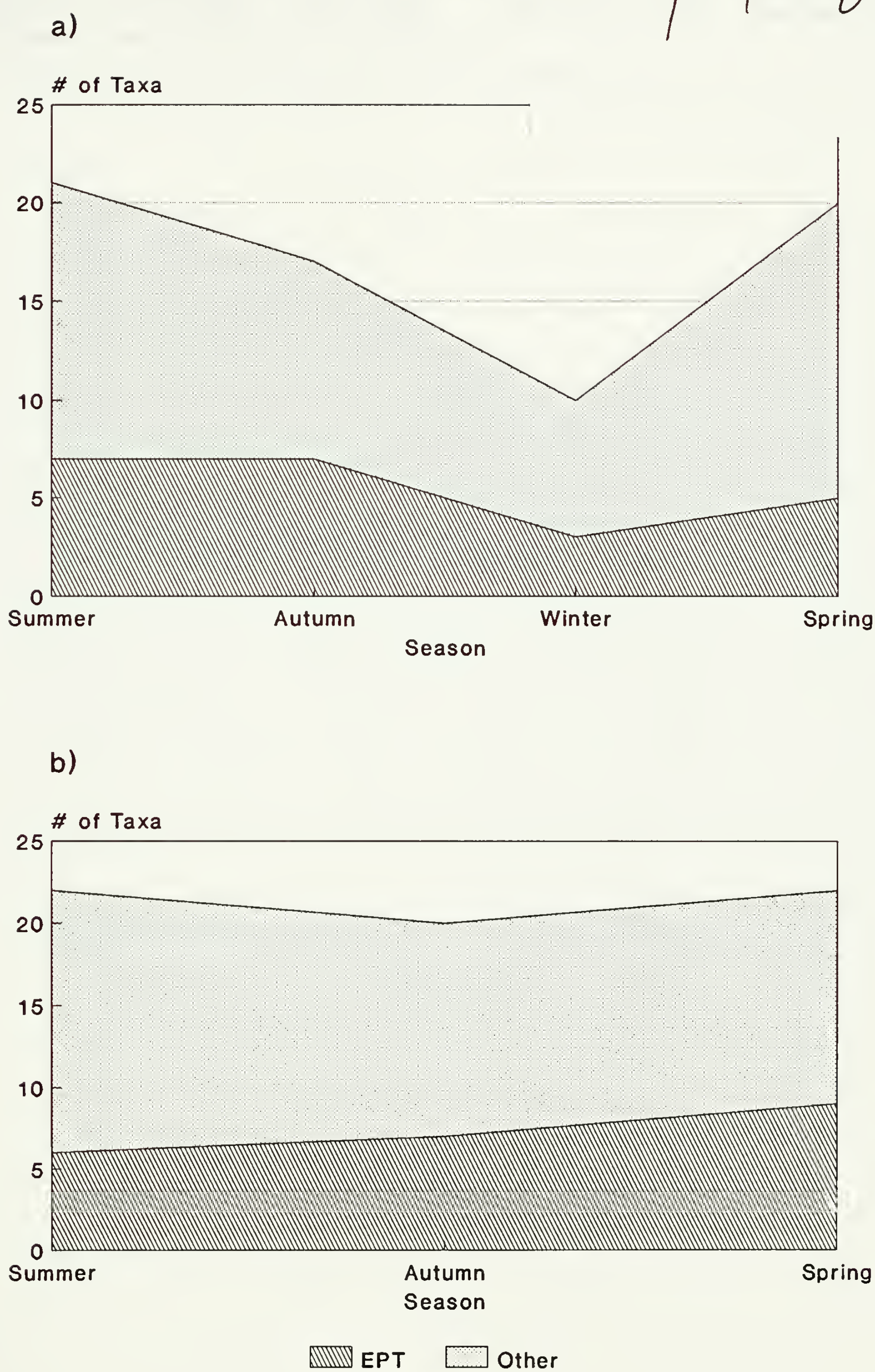
b)



H'
3
2.5
2
1.5
1
0.5
0
6/16 6/30 7/14 7/28 8/11 8/25 9/16 10/16 2/18
Date
1-D
1
0.8
0.6
0.4
0.2
0
6/16 6/30 7/14 7/28 8/11 8/25 9/16 10/16 2/18
Date
Site 1
Site 2
Site 3

Figure 4-7. Macroinvertebrate diversity on each Hess sampling date, Agate Fossil Beds National Monument, Nebraska, calculated by a) Shannon diversity, b) Simpson's complement.

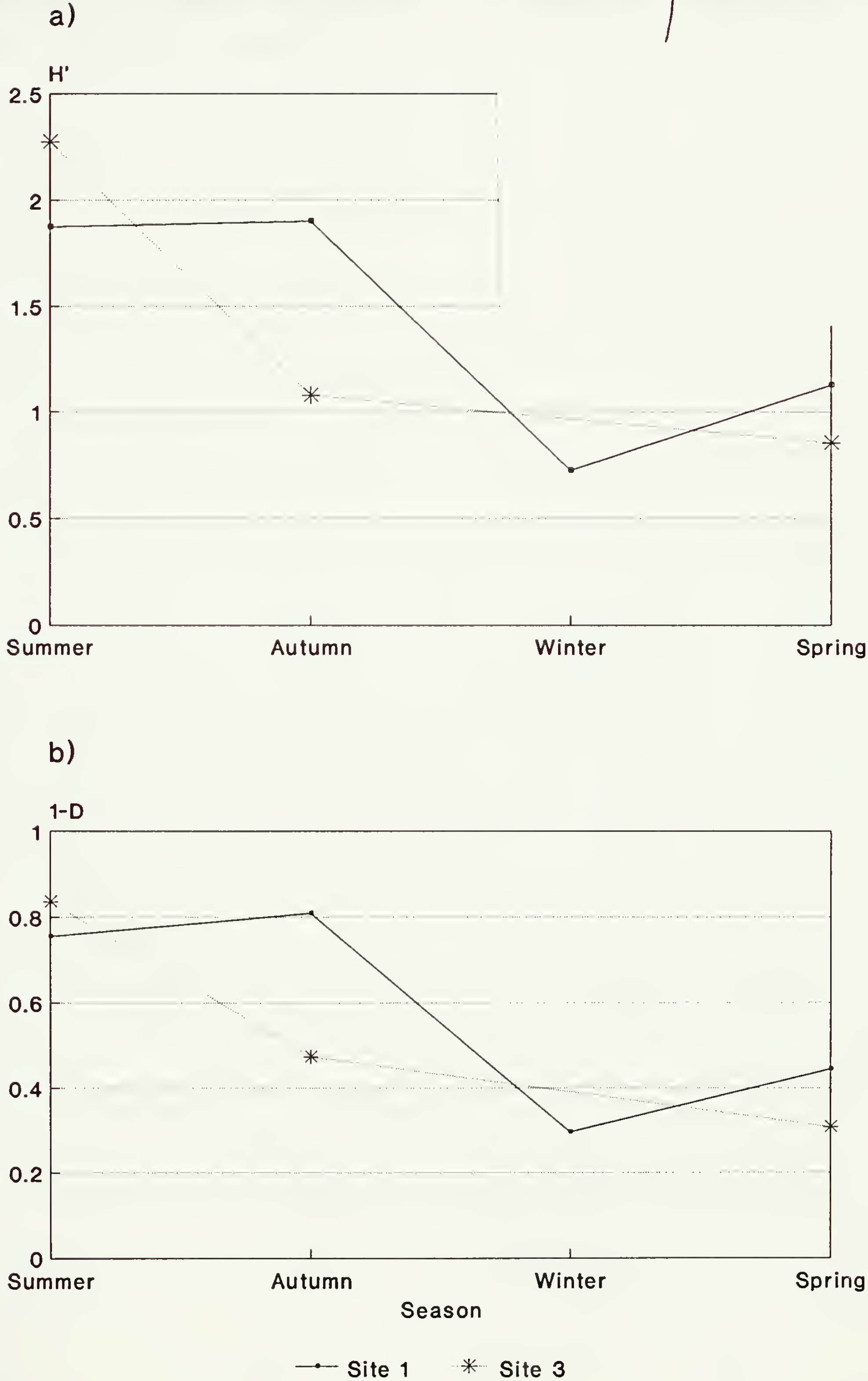
Fig 4-8



a)
# of Taxa
25
20
15
10
5
0
Summer
Autumn
Winter
Spring
Season
b)
# of Taxa
25
20
15
10
5
0
Summer
Autumn
Spring
Season
EPT
Other

Figure 4-8. Number of taxa in one of the three orders: Ephemeroptera, Plecoptera, Trichoptera (EPT taxa), Agate Fossil Beds National Monument, Nebraska, found on each Hester-Dendy sampling date for a) Site 1, b) Site 3.

Fig 4-9

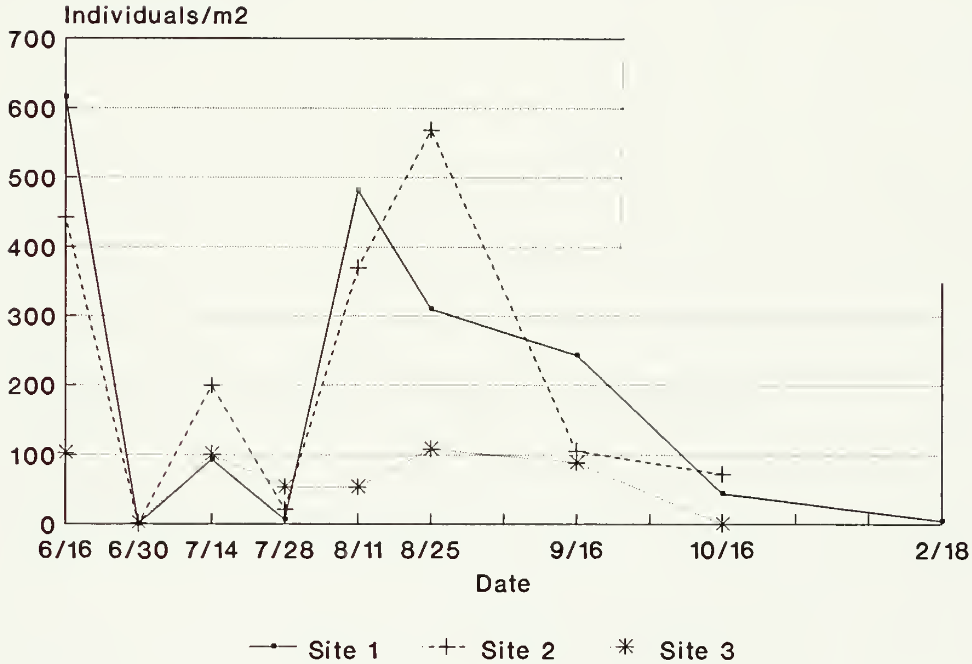


a)
H'
2.5
2
1.5
1
0.5
0
Summer
Autumn
Winter
Spring
b)
1-D
1
0.8
0.6
0.4
0.2
0
Summer
Autumn
Winter
Spring
Season
Site 1
Site 3

Figure 4-9. Macroinvertebrate diversity on each Hester-Dendy sampling date, Agate Fossil Beds National Monument, Nebraska, calculated by a) Shannon diversity, b) Simpson's complement.

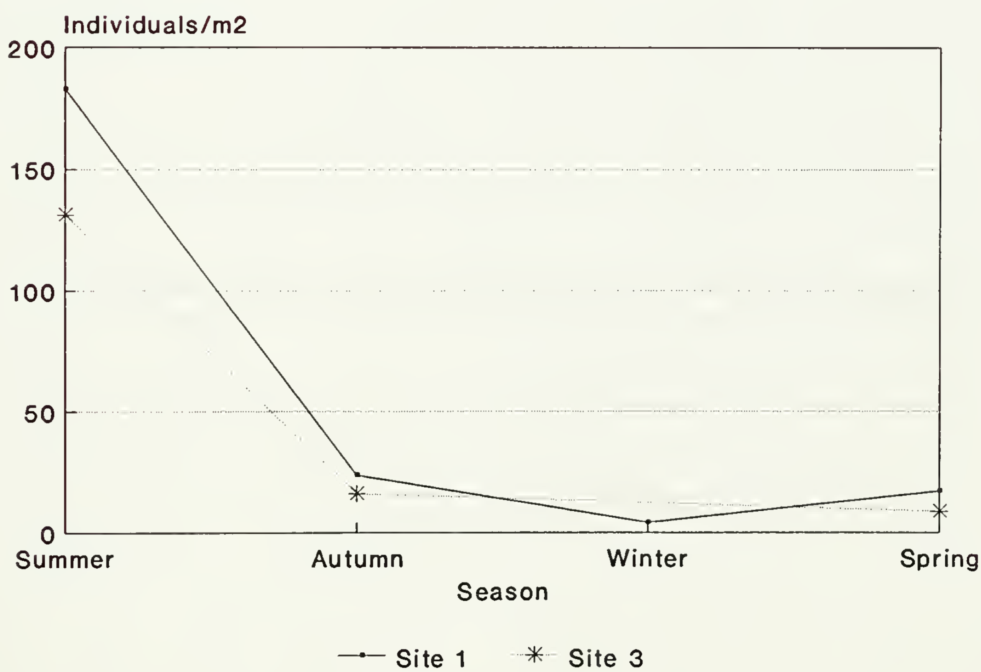
Fig 4-10

a)



Individuals/m2
700
600
500
400
300
200
100
0
6/16 6/30 7/14 7/28 8/11 8/25 9/16 10/16 2/18
Date
Site 1
Site 2
Site 3

b)

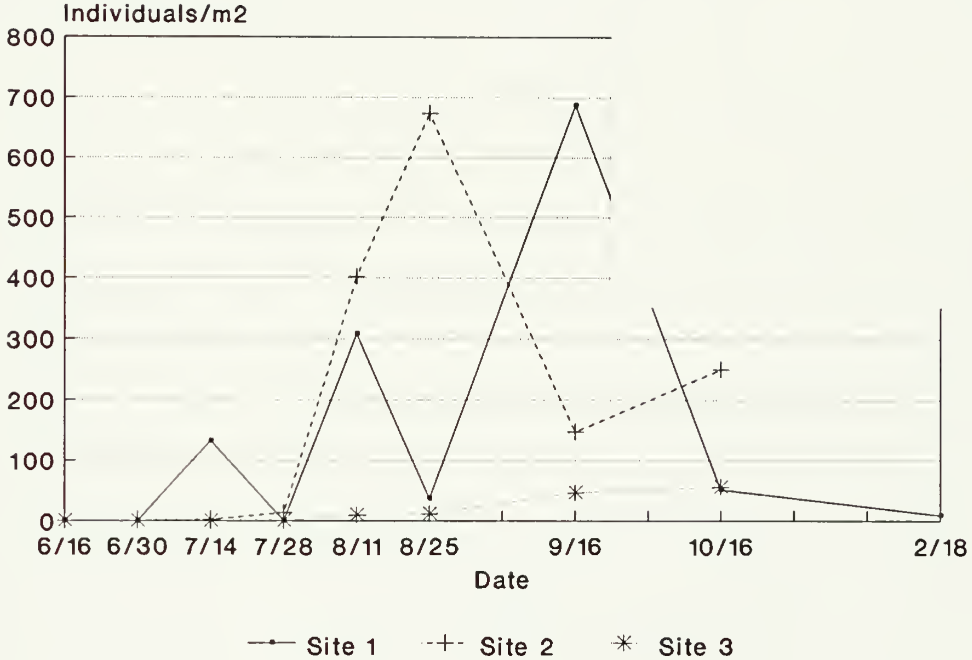


Individuals/m2
200
150
100
50
0
Summer
Autumn
Winter
Spring
Season
Site 1
Site 3

Figure 4-10. Baetidae density on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

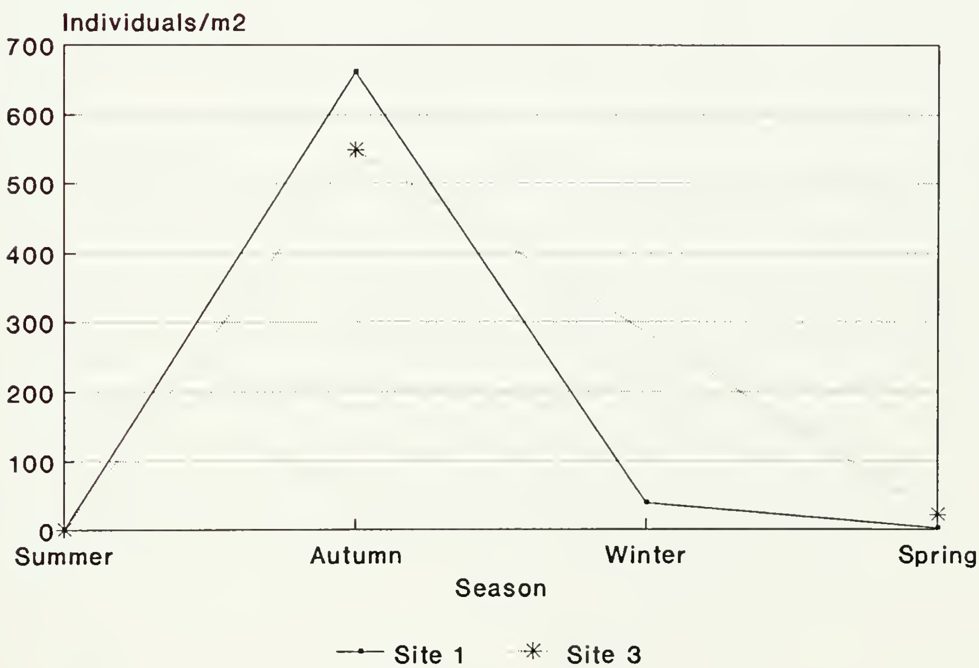
Fig 4-11

a)



Individuals/m2
800
700
600
500
400
300
200
100
0
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
2/18
Date
Site 1
Site 2
Site 3

b)

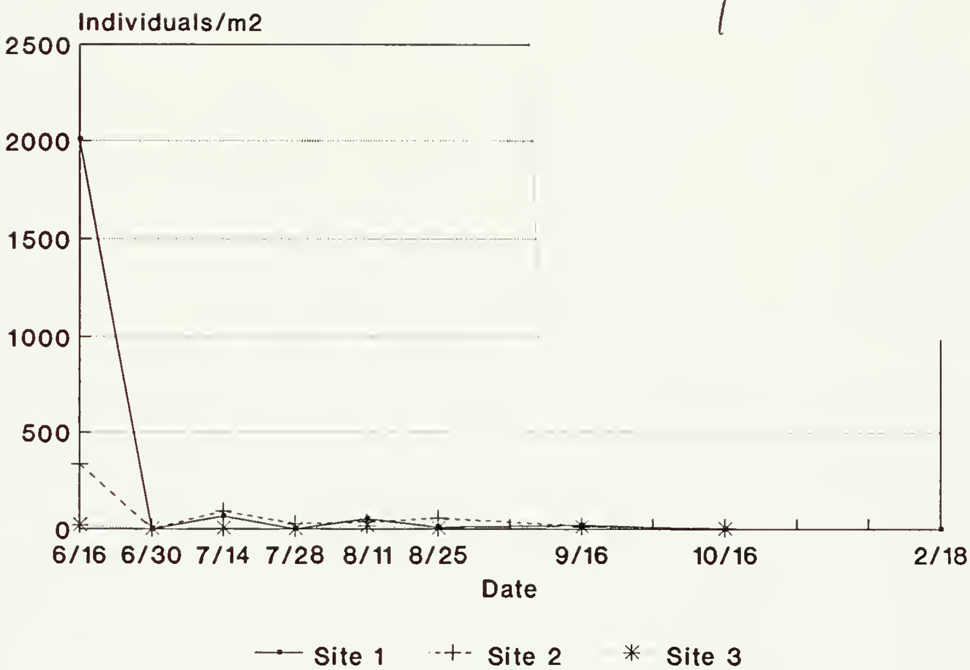


Individuals/m2
700
600
500
400
300
200
100
0
Summer
Autumn
Winter
Spring
Season
Site 1
Site 3

Figure 4-11. Leptophlebia density on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

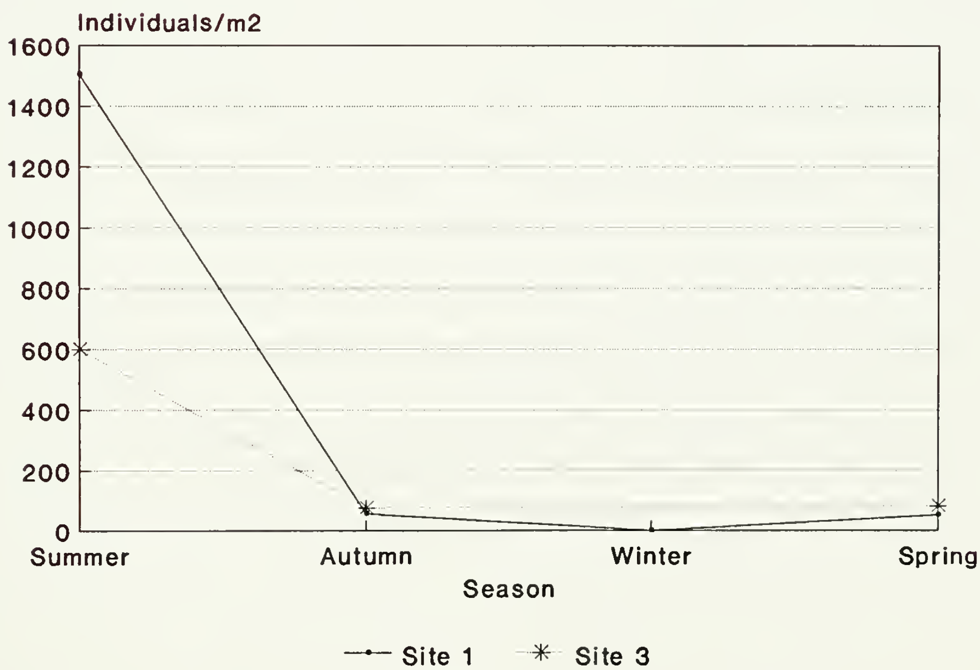
Fig 4-12

a)



Individuals/m2
2500
2000
1500
1000
500
0
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
2/18
Date
Site 1
Site 2
Site 3

b)



Individuals/m2
1600
1400
1200
1000
800
600
400
200
0
Summer
Autumn
Winter
Spring
Season
Site 1
Site 3

Figure 4-12. *Heptagenia* density on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

Hexagenia

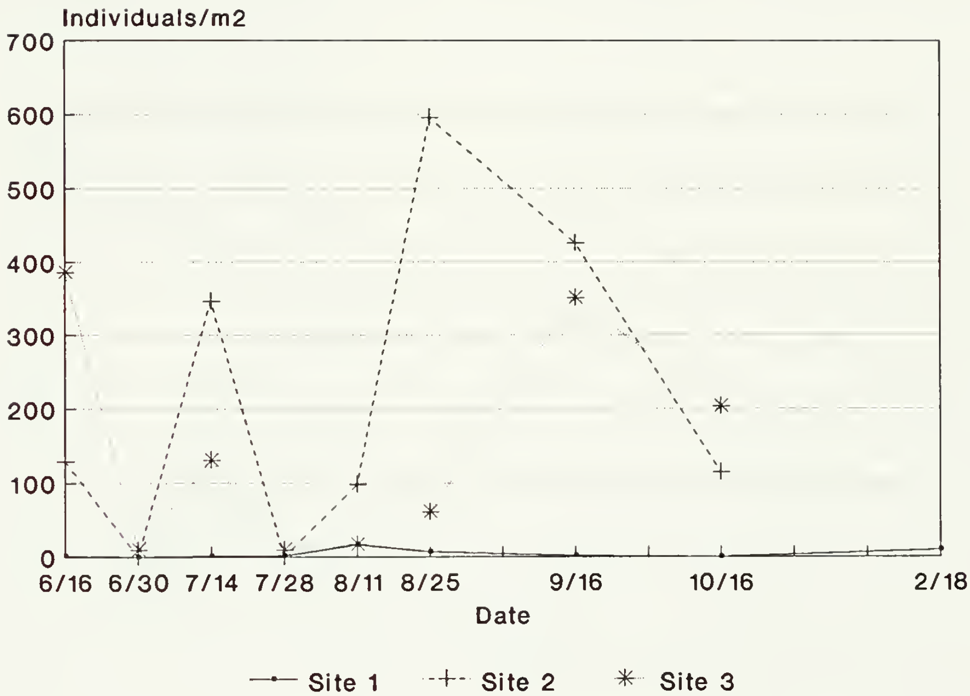


Fig 4-13

Figure 4-13. Hexagenia density on each Hess sampling date, Agate Fossil Beds National Monument, Nebraska.

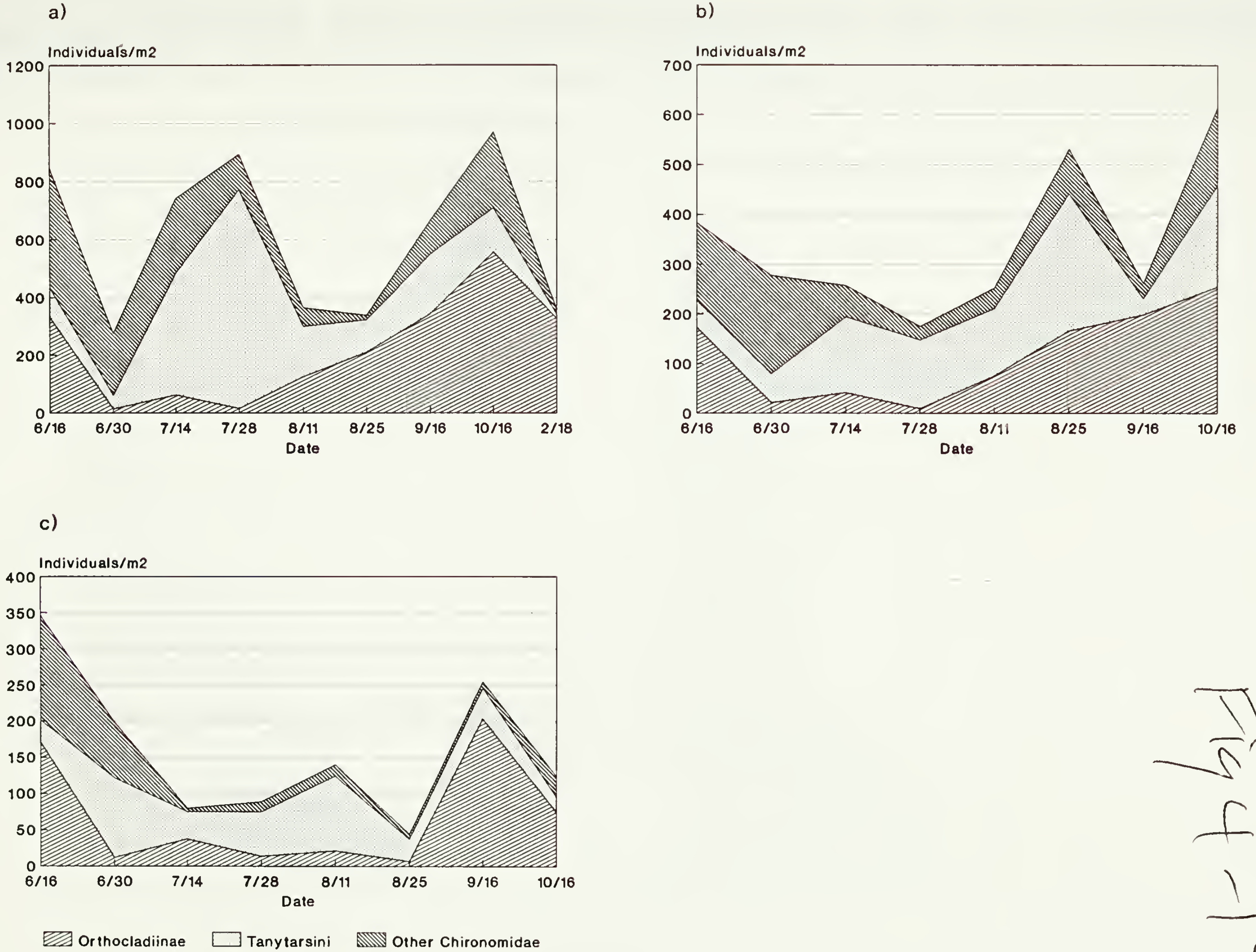

a)
Individuals/m2
1200
1000
800
600
400
200
0
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
2/18
Date
b)
Individuals/m2
700
600
500
400
300
200
100
0
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
Date
c)
Individuals/m2
400
350
300
250
200
150
100
50
0
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
Date
Orthocladiinae
Tanytarsini
Other Chironomidae

Fig 4-14

Figure 4-14. Chironomidae density on each Hess sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Site 1, b) Site 2, c) Site 3.

Fig. 4-15

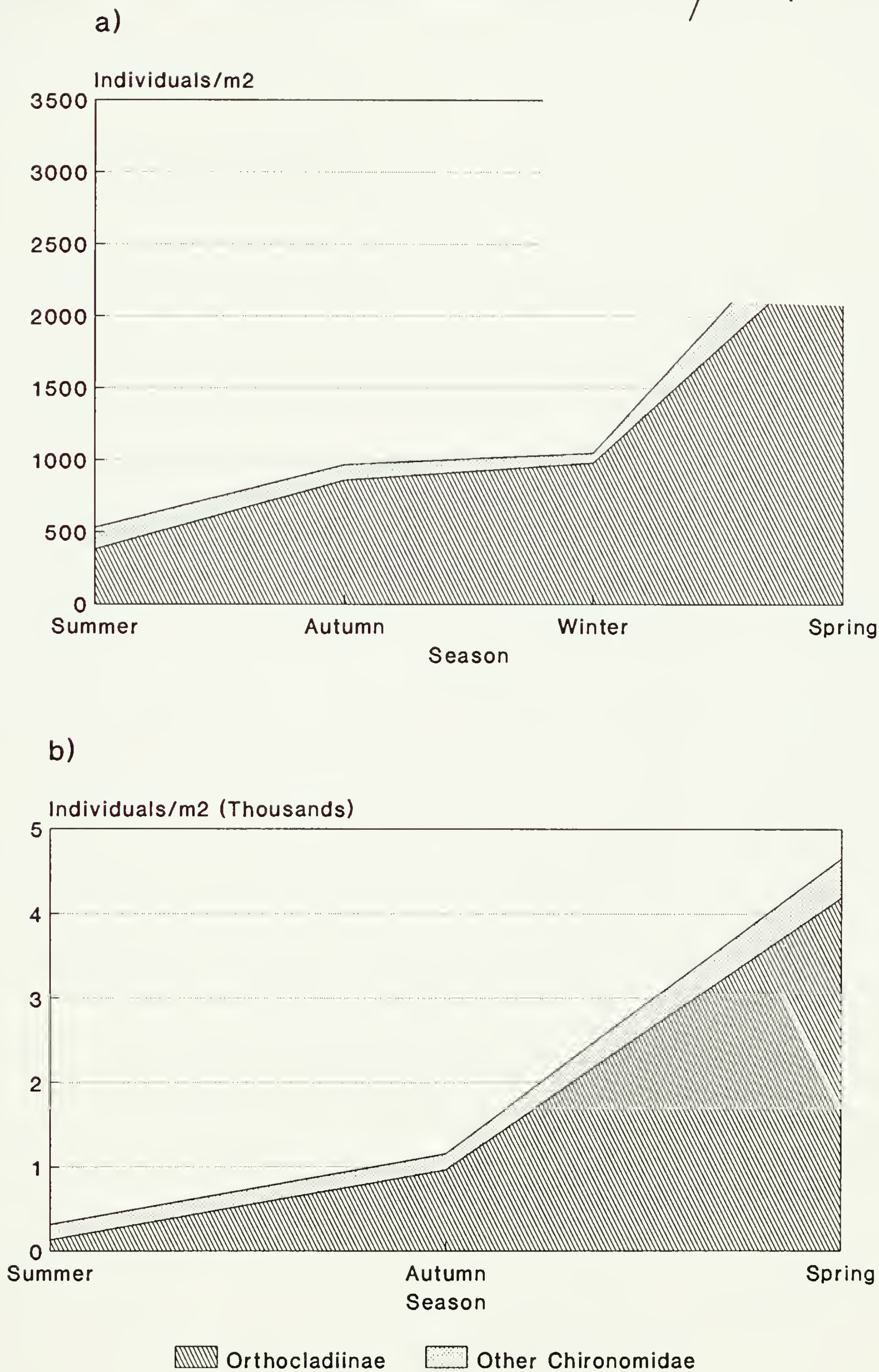
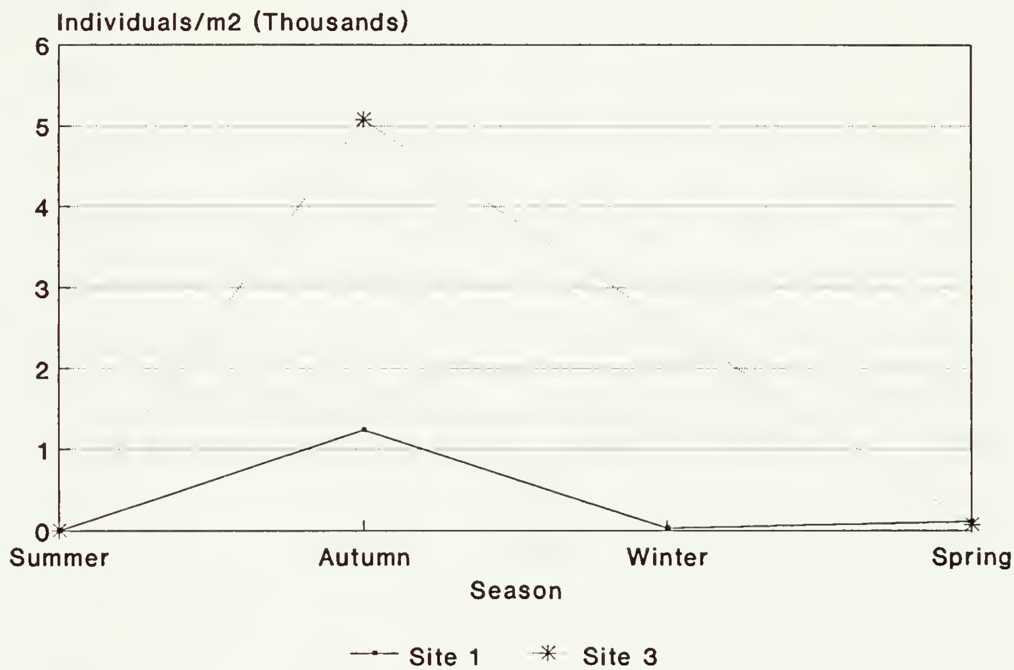

a)
Individuals/m2
3500
3000
2500
2000
1500
1000
500
0
Summer
Autumn
Winter
Spring
Season
b)
Individuals/m2 (Thousands)
5
4
3
2
1
0
Summer
Autumn
Spring
Season
Orthocladiinae
Other Chironomidae

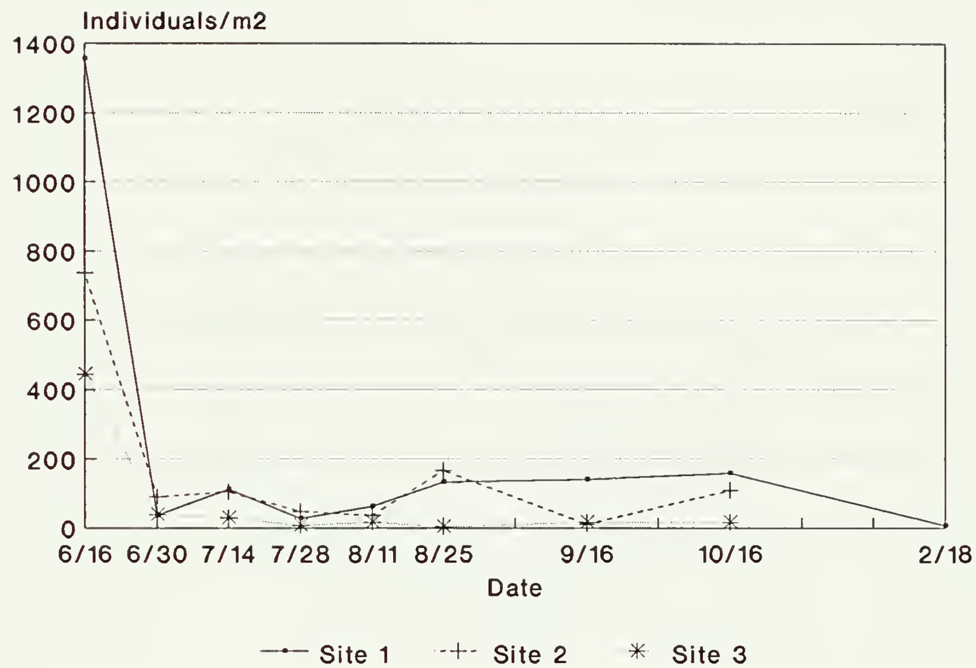
Figure 4-15. Chironomidae density on each Hester-Dendy sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Site 1, b) Site 3.

Figure 4-16. Simulium density on each Hester-Dendy sampling date, Agate Fossil Beds National Monument, Nebraska.



Oligochaete

a)



b)

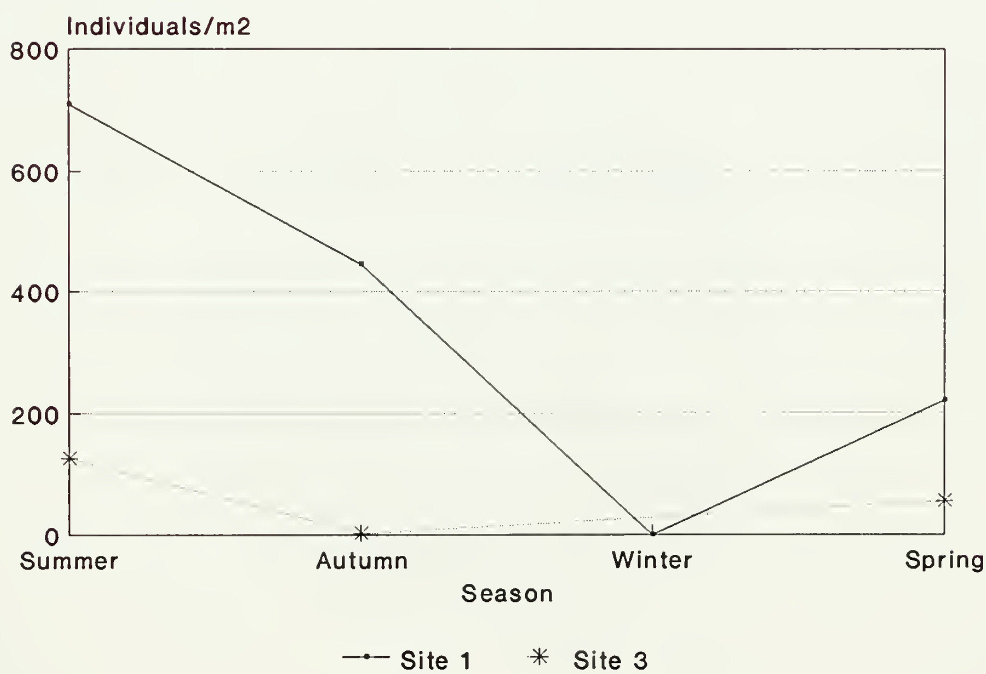
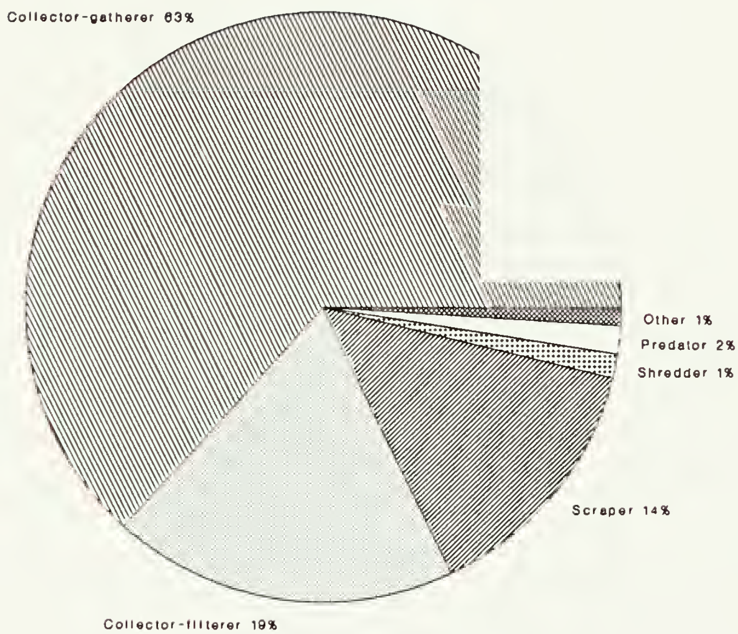


Fig. 4-17

Figure 4-17. Oligochaeta density on each sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Hess bottom sampler, b) Hester-Dendy multiple plate sampler.

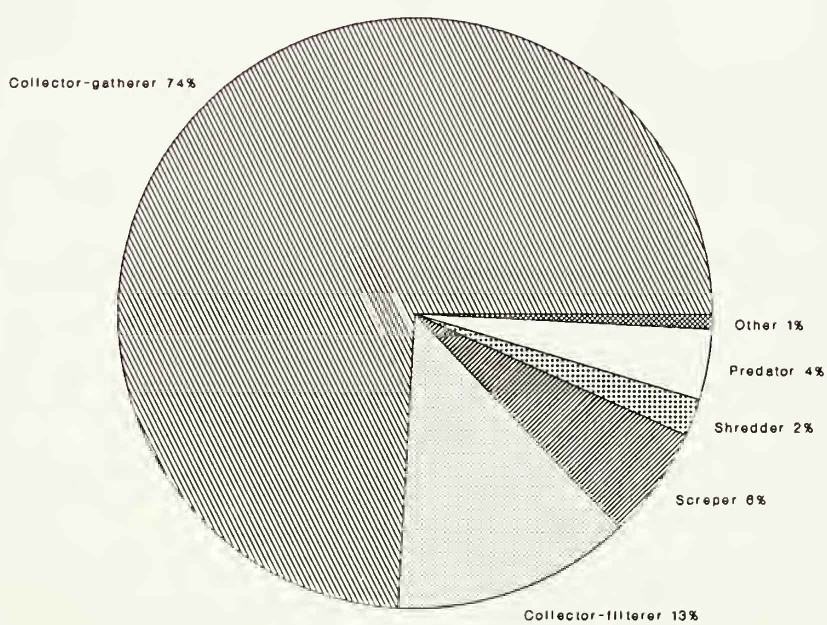
Fig. 4-18

a)



Collector-gatherer 63%
Other 1%
Predator 2%
Shredder 1%
Scraper 14%
Collector-filterer 19%

b)



Collector-gatherer 74%
Other 1%
Predator 4%
Shredder 2%
Scraper 6%
Collector-filterer 13%

Figure 4-18. Percent of functional groups during Hess sampling period, Agate Fossil Beds National Monument, Nebraska, for a) Site 1 (does not include winter sample), b) Site 2, c) Site 3.

c)

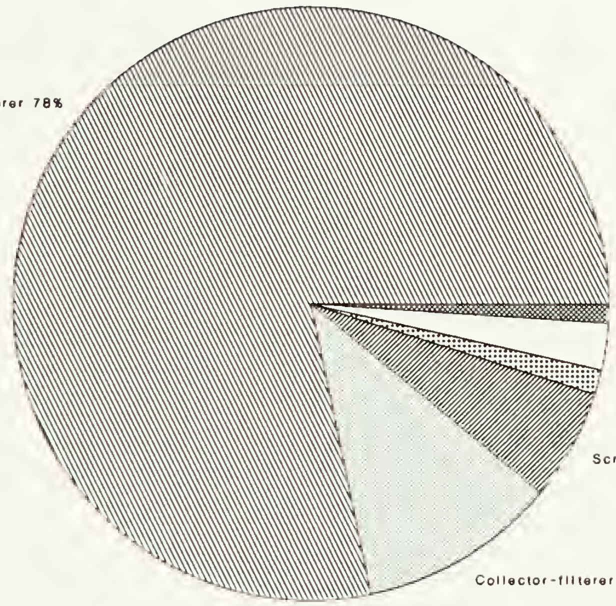
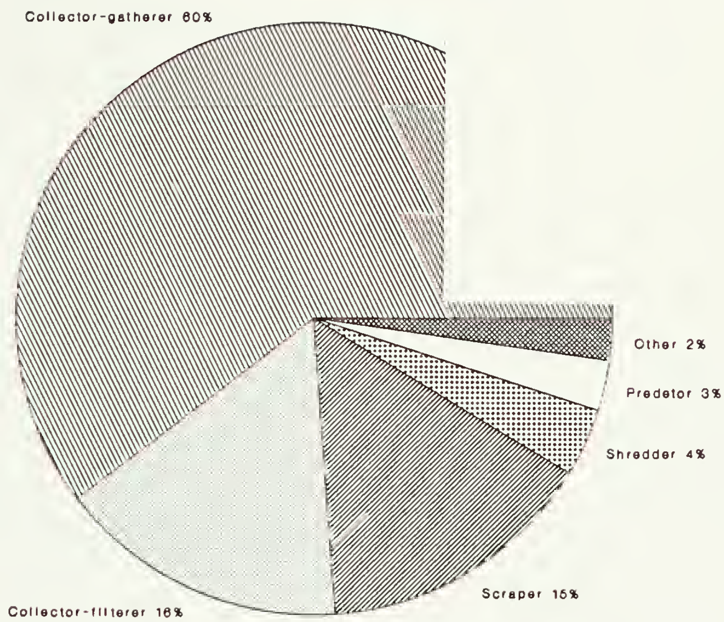


Fig. 4-18
(Continued)

Figure 4-18 (continued).

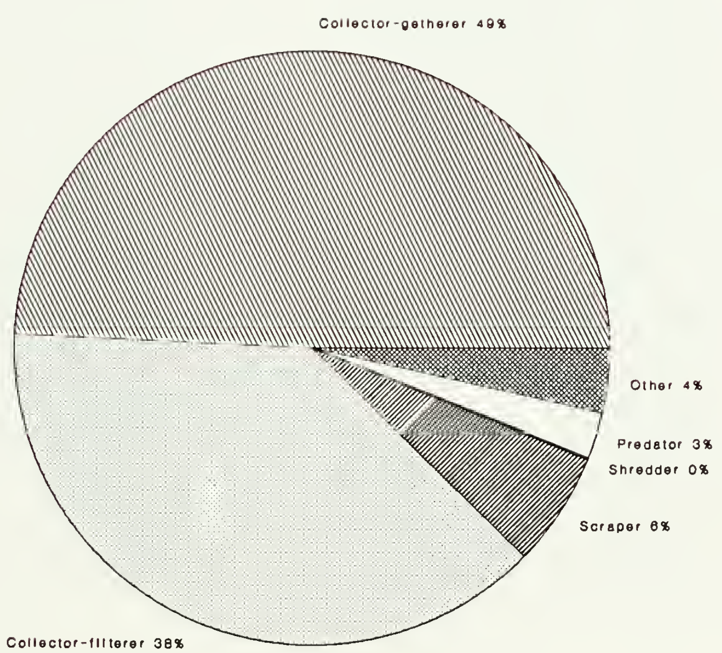
Fig. 4-19

a)



Collector-gatherer 60%
Other 2%
Predator 3%
Shredder 4%
Scraper 15%
Collector-filterer 16%

b)



Collector-gatherer 49%
Other 4%
Predator 3%
Shredder 0%
Scraper 6%
Collector-filterer 38%

Figure 4-19. Percent of functional groups during Hester-Dendy sampling period, Agate Fossil Beds National Monument, Nebraska, for a) Site 1 (does not include winter sample), b) Site 3.

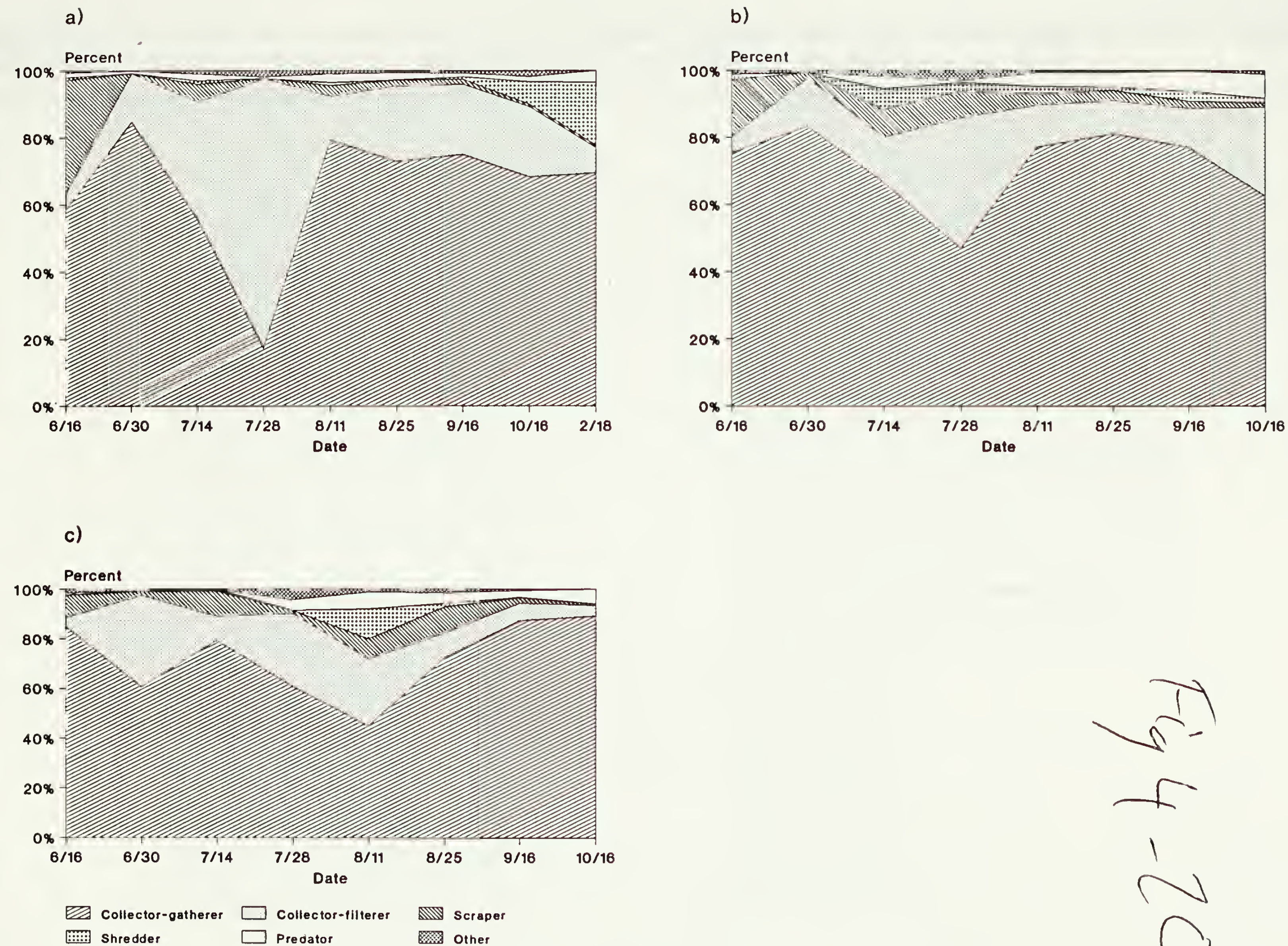

a)
Percent
100%
80%
60%
40%
20%
0%
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
2/18
Date
b)
Percent
100%
80%
60%
40%
20%
0%
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
Date
c)
Percent
100%
80%
60%
40%
20%
0%
6/16
6/30
7/14
7/28
8/11
8/25
9/16
10/16
Date
Collector-gatherer
Collector-filterer
Scraper
Shredder
Predator
Other

Fig 4-20

Figure 4-20. Cumulative percent of functional groups on each Hess sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Site 1, b) Site 2, c) Site 3.

Fig 4-21

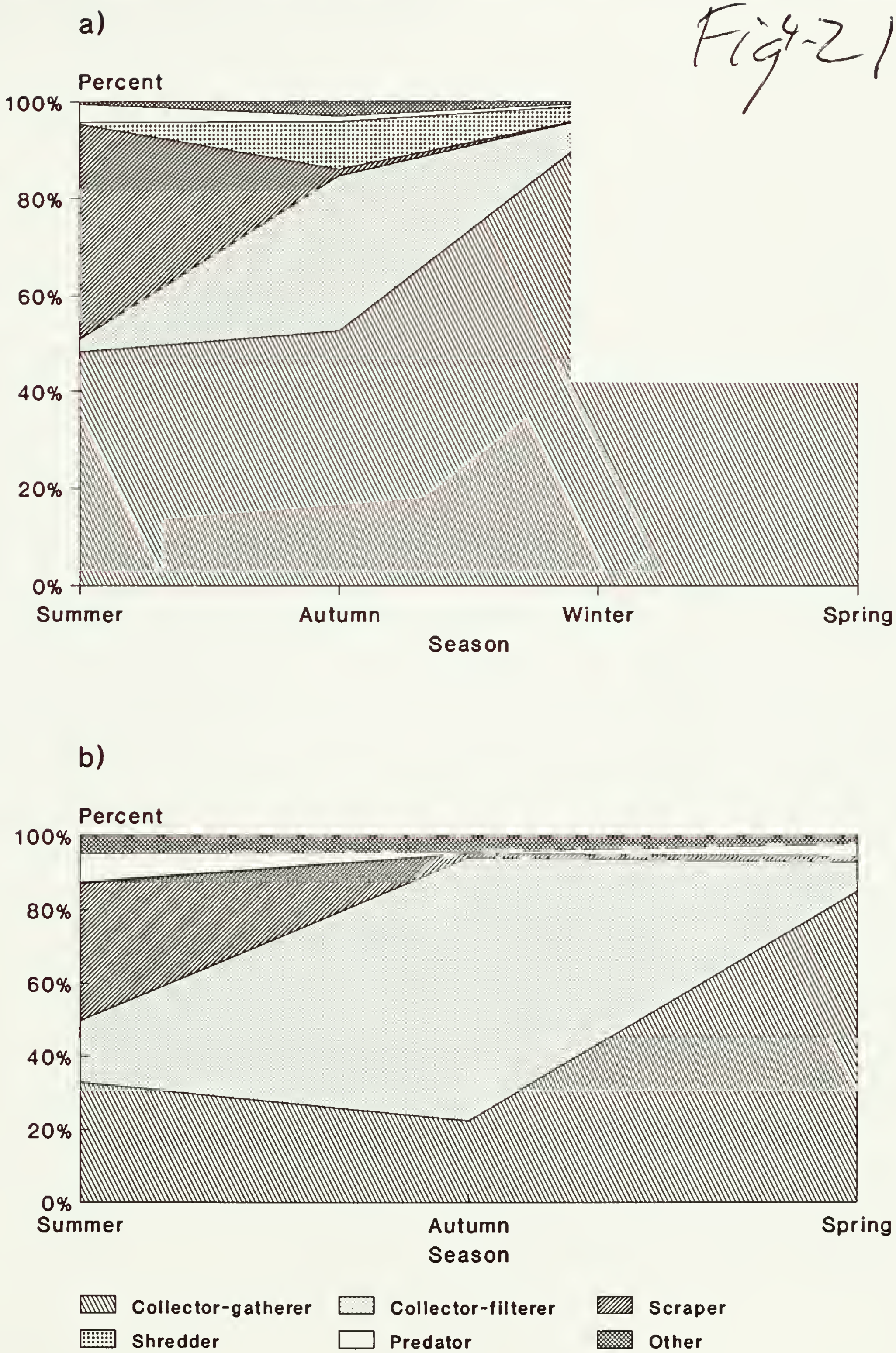
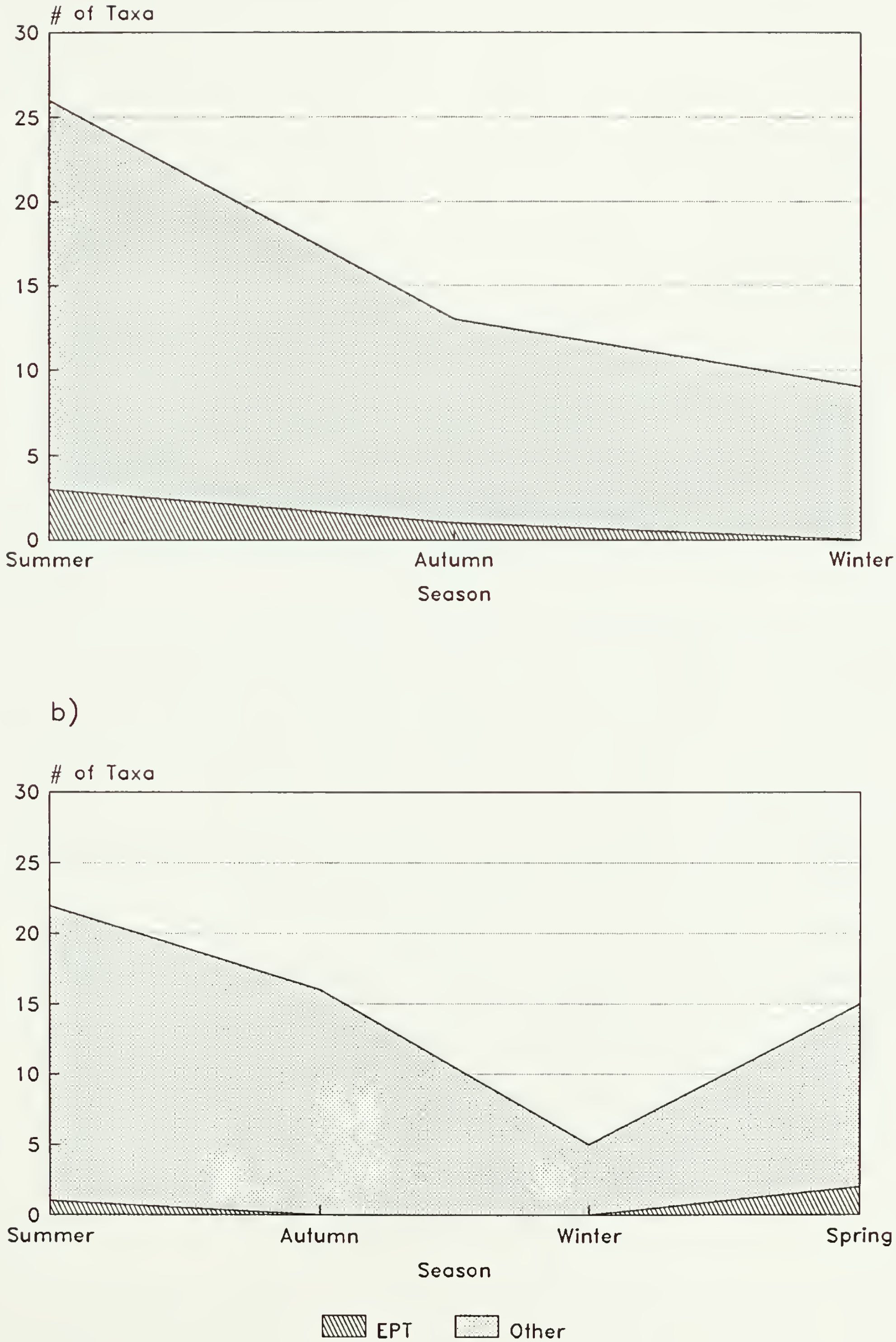

a)
Percent
100%
80%
60%
40%
20%
0%
Summer
Autumn
Winter
Spring
Season
b)
Percent
100%
80%
60%
40%
20%
0%
Summer
Autumn
Spring
Season
Collector-gatherer
Collector-filterer
Scraper
Shredder
Predator
Other

Figure 4-21. Cumulative percent of functional groups on each Hester-Dendy sampling date, Agate Fossil Beds National Monument, Nebraska, for a) Site 1, b) Site 3.

a)

b)



# of Taxa
30
25
20
15
10
5
0
Summer
Autumn
Winter
Season
# of Taxa
30
25
20
15
10
5
0
Summer
Autumn
Winter
Spring
Season
EPT
Other

Figure 4-22. Number of taxa in one of the three orders Ephemeroptera, Plecoptera, Trichoptera (EPT), and taxa in other groups (Other), for a) Site 1 and b) Site 2, Cub Creek, Homestead National Monument of America, Nebraska.

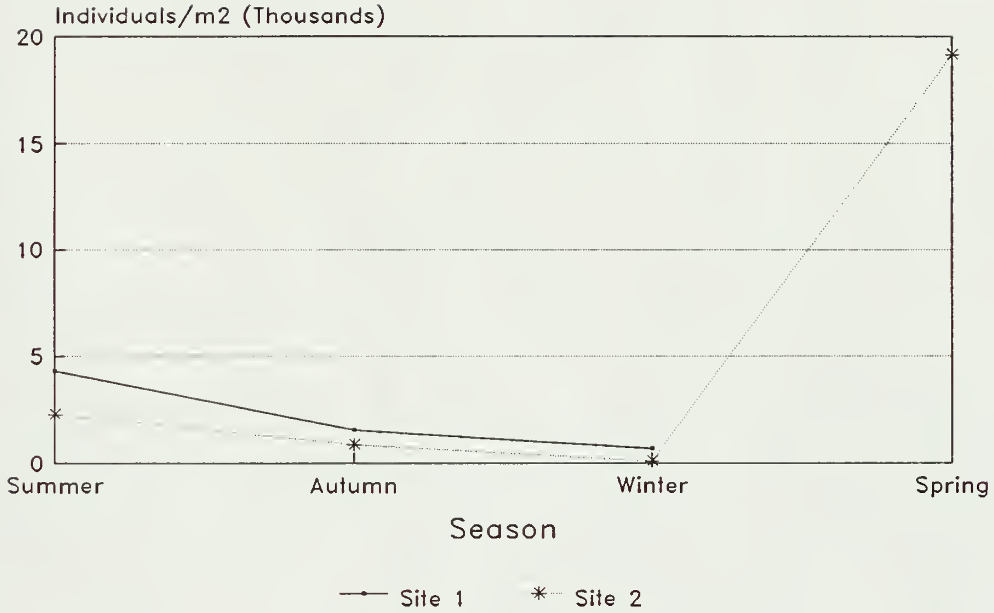


Fig. 4-23

Hans
Density

Fig. 4-23 (Caption in Book #2)